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Merchantable and Sawtimber Volumes for Natural Even-Aged Stands of Loblolly Pine in the West Gulf Region

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SUMMARY

Equations are presented for estimating merchantable and sawtimber volumes for natural even-aged stands of loblolly pine in the West Gulf Coastal Plain for woods-run conditions. The equation system can be used to predict current and projected volumes for cubic feet and board feet (Doyle, Scribner, and International ¼-inch).

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INTRODUCTION

Loblolly pine (*Pinus taeda* L.) is the predominent commercial pine species on the West Gulf Coastal Plain — south Arkansas, Louisiana, and east Texas. Despite its importance, information regarding sawtimber yields of natural even-aged stands on this region is lacking. Sawtimber information for normally stocked stands on the West Gulf is available (U.S.D.A. Forest Service 1976, Meyer 1942), but not for stands with variable densities. Results for variable densities given by Schumacher and Coile (1960), Brender and Clutter (1970), and Burkhart et al. (1972) were developed for the Southeast.

This paper presents equations for determining current and projected board-foot volumes (Doyle, International ¼-inch, and Scribner log rules), current and projected cubic-foot volumes (merchantable and sawtimber), and projected sawtimber and merchantable basal areas for natural even-aged stands of loblolly pine on the West Gulf Coastal Plain. Because improved basal area projection equations have been developed, the findings presented here supersede previous results found in Murphy and Sternitzke (1979).

DATA

Forest Survey

Part of the information utilized in this study is from forest surveys conducted by the Forest Inventory and Analysis Unit of the Southern Forest Experiment Station, USDA — Forest Service, as part of a nationwide Forest Survey. Plot locations are at the intersections of a 3-mile square grid. Information is collected according to standard procedures (Renewable Resources Evaluation Staff 1978) at forested locations. Plots consist of 10-point samples systematically dispersed 66 feet apart over about 1 acre.

Forest Survey data for the West Gulf Coastal Plain had been used previously for developing equations to predict current and projected merchantable cubic-foot volumes and projected merchantable basal areas for loblolly pine (Murphy and Sternitzke 1979). About 145 plots were used at that time, and they had to conform to the following requirements: (1) at least half of the merchantable basal area (trees 5 inches dbh or larger) in the initial survey was loblolly pine; (2) all ten points were recovered in the remeasurement survey; (3) site tree information was collected from loblolly sample trees; (4) there was no catastrophic mortality; (5) the stands were even-aged and natural in origin; and (6) there was no disturbance by logging or other activity between measurements. The time between surveys averaged ten years. The general location and dates of the surveys are south Arkansas, 1969 and 1978; Louisiana, 1964 and 1974; and east Texas, 1965 and 1975.

The same data were used for the present study. Table 1 gives the plot distribution by age, site index (base age 50), and loblolly merchantable basal area per acre at the initial measurement. Geographical locations are shown in figure 1.

Merchantable cubic-foot volumes (ib) from a 1-foot stump to a 4-inch top (ob), were calculated for 3,499 loblolly pine trees, 5 inches dbh and larger, using upper stem measurements that were collected during the remeasurement surveys. Sawtimber cubic-foot volumes (ib) from a 1-foot stump to a 7-inch top (ob) were calculated for 2,818 loblolly pine trees, 9 inches dbh and larger, also using upper stem measurements. Board-foot volumes (Doyle, International ¼-inch, and Scribner) were determined for the same 2,818 trees by 16-foot logs with a 0.3-foot trim allowance and for the top section to a 7-inch top (ob).

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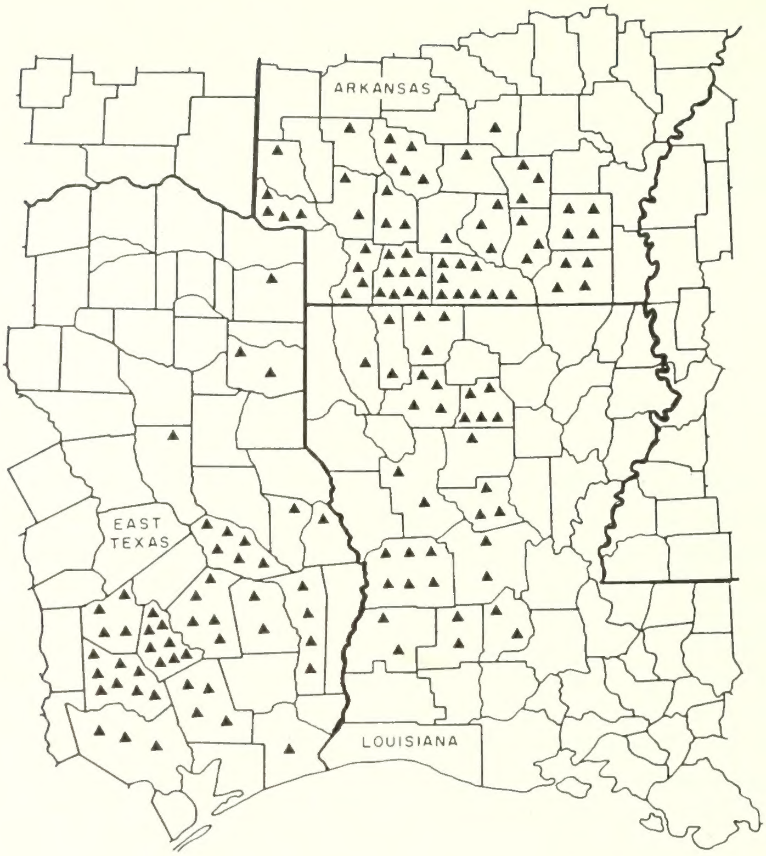

Figure 1.—*Geographical distribution of 145 Forest Survey sample plots in Arkansas, Louisiana, and Texas.*

Volume equations were fitted using these individual tree volumes as data. For cubic volume, the functions fitted by weighted least squares (SAS Institute 1979) were:

$Y_m = \lambda_0 + \lambda_1 D^2 H_m$

$Y_s = \rho_0 + \rho_1 D^2 H_s$,

where

Y_m = merchantable cubic-foot volume,

Y_s = sawlog cubic-foot volume,

D = diameter breast height (ob) in inches,

H_m = merchantable height, in feet, from a 1-foot stump to a 4-inch top (ob),

H_s = sawlog height, in feet, from a 1-foot stump to a 7-inch top (ob),

$1/D^2H_m$ = weight for merchantable volume,

$1/D^2H_s$ = weight for sawlog volume,

λ_i, ρ_i = coefficients to be estimated.

The resulting equations are:

$Y_m = 0.41957 + 0.0025391 D^2 H_m, R^2 = 0.976$

$Y_s = 2.1607 + 0.0022992 D^2 H_s, R^2 = 0.962$.

Board-foot volumes for the three log rules were fitted by least squares using the equation:

$\ln(L) = \theta_0 + \theta_1 \ln(D) + \theta_2 \ln(H_s)$,

where

L = board-foot volumes, inside bark, from a 1-foot stump to a 7-inch top (ob),

θ_i = coefficients to be estimated,

and ln denotes the logarithm to the base *e*. The variables D and H_s have already been defined. Table 2 gives the coefficient estimates and the associated R^2's.

The following plot variables were determined for loblolly pine: (1) site index from equations developed by Farrar (1975), (2) stand age in years at both measurements, (3) merchantable basal area per acre of trees 5 inches and larger at the first measurement and of the same trees at remeasurement, (4) the merchantable volume of these trees at both measurements, (5) basal area per acre of sawtimber trees 9 inches or larger at either measurement, and (6) the cubic-foot volume and board-foot volume in the sawlog portion of these same sawtimber trees for both measurements. The plot summarization procedures by Beers and Miller (1964) were followed.

Arkansas

Additional data were utilized from information collected by Ku, Sweeney, and Shelburne (1977). These data were part of a cooperative study by the Department of Forestry at the University of Arkan-

Table 1.—*Plot distribution by age, site index (base age 50), and loblolly pine merchantable basal area at initial measurement for Forest Survey plots*

Age	Site index	Basal area per acre (ft^2)						
		<20	21–40	41–60	61–80	81–100	101+	
years	*feet*	*number of plots*						*total*
≤20	≤70	....	....	....	....	....	....	....
	71–80	2	....	....	....	....	....	2
	81–90	5	3	....	1	....	....	9
	91–100	....	6	3	....	....	....	9
	101+	3	9	2	1	2	....	17
	Total	10	18	5	2	2	0	37
21–30	≤70	....	1	....	....	....	....	1
	71–80	5	7	4	....	....	....	16
	81–90	2	8	8	3	....	1	22
	91–100	1	5	9	4	....	....	19
	101+	....	0	2	2	....	....	4
	Total	8	21	23	9	0	1	62
31–40	≤70	....	....	....	....	....	....	....
	71–80	1	....	1	1	....	....	3
	81–90	....	2	4	2	3	....	11
	91–100	....	2	4	3	1	2	12
	101+	....	....	....	....	1	1	2
	Total	1	4	9	6	5	3	28
41–50	≤70	....	....	....	....	....	....	....
	71–80	....	1	2	....	....	....	3
	81–90	....	....	1	2	....	....	3
	91–100	....	....	1	1	....	....	2
	101+	....	....	1	....	1	....	2
	Total	0	1	5	3	1	0	10
51+	≤70	....	....	....	....	....	....	....
	71–80	....	1	2	....	1	....	4
	81–90	....	....	....	1	1	....	2
	91–100	....	....	1	1	....	....	2
	101+	....	....	....	....	....	....	....
	Total	0	1	3	2	2	0	8
All ages	≤70	....	1	....	....	....	....	1
	71–80	8	9	9	1	1	....	28
	81–90	7	13	13	9	4	1	47
	91–100	1	13	18	9	1	2	44
	101+	3	9	5	3	4	1	25
	Total	19	45	45	22	10	4	145

sas at Monticello and the Arkansas Forestry Commission to gather data in Arkansas on site and stand information in stands infested with the southern pine beetle (*Dendroctonus frontalis* Zimm.). Some 227 plots were also installed to collect baseline information on average stand conditions in south Arkansas. The baseline plots were distributed one per township in counties comprising the study area; the data were collected on variable radius plots in 1976–1977.

One hundred fifty-one of these plots were selected to supplement the Forest Survey data for a better representation by age, site, and density (see table 3). Plots had to meet the same criteria and were summarized in the same manner described in the previous section. The location of the 151 plots by counties is shown in figure 2.

Table 2.—*Coefficients for board-foot volume equations*

Log rule	Estimate			R-square[1]
	θ_0	θ_1	θ_2	
Doyle	−7.8923	3.1146	1.0523	0.951
Scribner	−5.1282	2.3662	0.97602	0.956
International ¼-inch	−4.3121	2.1369	0.96865	0.959

[1] Logarithmic scale, base *e*

MODEL DEVELOPMENT

A set of equations for predicting projected merchantable and sawtimber basal areas as well as current and projected volumes has been developed (Murphy 1983) and was extended here to include board-foot volumes. The equation system is:

$$(1)\ \hat{B}_{m2} = [n_1/k_1 - [n_1/k_1 - B_{m1}^{(1-m_1)}](A_2/A_1)^{-k_1(1-m_1)}]^{1/(1-m_1)},$$

$$(2)\ \hat{B}_{s2} = B_{m2}\,[1 - [1 - (B_{s1}/B_{m1})^{(1-m_2)}](A_2/A_1)^{-k_2(1-m_2)}]^{1/(1-m_2)},$$

$$(3)\ \hat{C}_{mi} = \exp[\alpha_0 + \alpha_1 Q + \alpha_2/A_i + \alpha_3 \ln(B_{mi}]\ ,$$

$$(4)\ \hat{C}_{si} = \exp[\beta_0 + \beta_1 Q + \beta_2/A_i + \beta_3 \ln(B_{si})]\ ,$$

$$(5)\ \hat{D}_i = \exp[\gamma_0 + \gamma_1 Q + \gamma_2/A_i + \gamma_3 \ln(B_{si})],$$

$$(6)\ \hat{S}_i = \exp[\sigma_0 + \sigma_1 Q + \sigma_2/A_i + \sigma_3 \ln)B_{si})],$$

$$(7)\ \hat{I}_i = \exp[\phi_0 + \phi_1 Q + \phi_2/A_i + \phi_3 \ln(B_{si})],$$

where

B_{mi} = basal area in square feet per acre of loblolly pine trees 5 inches dbh and larger, at the ith occasion;

A_i = stand age, in years, at the ith occasion;

B_{si} = basal area in square feet per acre of loblolly pine trees 9 inches dbh and larger, at the ith occasion;

Q = site index in feet at base age 50,

C_{mi} = cubic-foot volume (ib) per acre of loblolly pine trees 5 inches dbh and larger from a 1-foot stump height to a 4-inch top diameter (ob) at the ith occasion;

C_{si} = cubic-foot volume (ib) per acre of loblolly pine trees 9 inches dbh and larger, from a 1-foot stump to a 7-inch top diameter (ob) at the ith occasion;

D_i = board-foot volume per-acre (Doyle measure) of loblolly pine trees 9 inches dbh and larger, from a 1-foot stump to a 7-inch top diameter (ob) at the ith occasion;

S_i = board-foot volume per-acre (Scribner measure) of loblolly pine trees 9 inches dbh and larger, from a 1-foot stump to a 7-inch top diameter (ob) at the ith occasion;

I_i = board-foot volume per-acre (International ¼-inch measure) of loblolly pine trees 9 inches dbh and larger, from a 1-foot stump

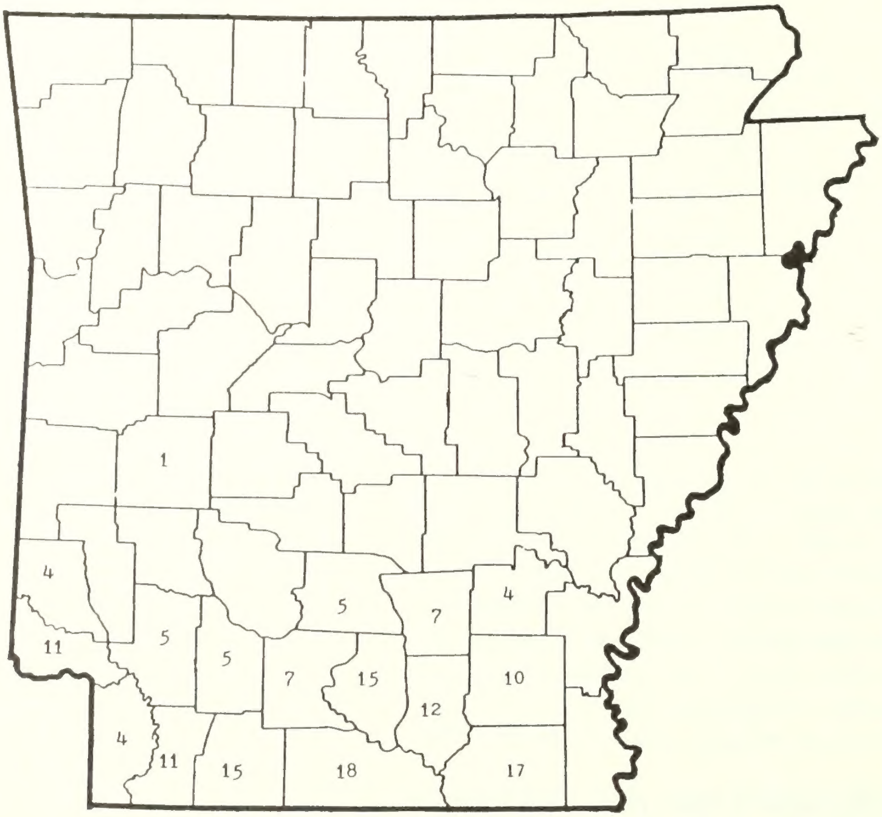

Figure 2.—*Geographic distribution of 151 supplementary plots in south Arkansas.*

to a 7-inch top diameter (ob) at the ith occasion;

n_i, m_i, k_i, α_i, β_i, γ_i, σ_i, and ϕ_i are coefficients to be estimated; ln is the logarithm to the base e; and exp denotes the exponent of e.

Note that sawtimber basal area is a component of merchantable basal area by definition. The equations were fitted using nonlinear seemingly unrelated regressions (SAS Institute 1980). For details on using this technique for fitting growth and yield equations, see Murphy (1983). The basal area equations were fitted using the 145 Forest Survey Plots. The stand volume equation coefficients were determined using both beginning and ending volumes from the Forest Survey plots (290 observations) and the Arkansas data (151 observations) for a total of 441 observations.

The resulting equations for predicting merchantable and sawtimber basal area per acre, respectively, are

$$\hat{B}_{m2} = \left[.0020518/1.5662 - \left[.0020518/1.5662 - B_{m1}^{(1-2.2332)} \right] (A_2/A_1)^{1.5662(1-2.2332)} \right]^{1/(1-2.2332)},$$

Table 3.—*Plot distribution by age, site index (base age 50), and loblolly pine merchantable basal area for Arkansas plots*

Age	Site index	Basal area per acre (ft^2)						
		≤20	21–40	41–60	61–80	81–100	101+	
years	*feet*	*number of plots*						*total*
	≤70					1		1
≤20	71–80	1		2				3
	81–90					2	1	3
	91–100			1	1	2		4
	101+	1	2	2	1	1	2	9
	Total	2	2	5	2	6	3	20
21–30	≤70	1	1	1	1	1		5
	71–80	1	1	2	1		1	6
	81–90	2		1	1	2	1	7
	91–100			1	4	1	7	13
	101+			1	2	2	2	7
	Total	4	2	6	9	6	11	38
31–40	≤70		3	1	2			6
	71–80	3		6	3	3	1	16
	81–90	1	5	2	4	2	4	18
	91–100		1	2	1	1	1	6
	101+	1						1
	Total	5	9	11	10	6	6	47
41–50	≤70	2	1	1	3			7
	71–80	1		3				4
	81–90	1	4	2	1	1		9
	91–100					2		2
	101+				1			1
	Total	4	5	6	5	3	0	23
51+	<70	1	3	1				5
	71–80		2	4				6
	81–90	2	3		1			6
	91–100		2	1	2		1	6
	101+							0
	Total	3	10	6	3	0	1	23
All ages	≤70	4	8	4	6	2		24
	71–80	6	3	17	4	3	2	35
	81–90	6	12	5	7	7	6	43
	91–100		3	5	8	6	9	31
	101+	2	2	3	4	3	4	18
	Total	18	28	34	29	21	21	151

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$$\hat{B}_{s2} = \hat{B}_{m2}\left[1 - [1 - (B_{s1}/B_{m1})^{(1-0.18171)}]\,(A_2/A_1)^{-3.0768(1-0.18171)}\right]^{1/(1-0.18171)}$$

The following equations are used to predict stand volumes,

$$\hat{C}_{mi} = \exp\,[2.9679 + 0.01076Q - 22.785/A_i + 0.98590\ln(B_{mi})]\ ,$$

$$\hat{C}_{si} = \exp\,[3.0350 + 0.0096502Q - 22.595/A_i + 0.95222\ln(B_{si})]\ ,$$

$$\hat{D}_i = \exp\,[4.8481 + 0.020742Q - 45.895/A_i + 0.74294\ln(B_{si})]\ ,$$

$$\hat{S}_i = \exp\,[4.9716 + 0.013965Q - 32.890/A_i + 0.87555\ln(B_{si})]\ ,$$

$$\hat{I}_i = \exp\,[5.0598 + 0.012151Q - 29.448/A_i + 0.91106\ln(B_{si})]\ .$$

An evaluation of the predictive abilities of the different equations is contained in table 4. The mean difference criterion indicates that the basal area equations have a slight negative bias. Percent root mean square errors are less than or equal to 34 percent for volumes, except for the Doyle rule. The larger variation in Doyle is due to the inherent nature of this log rule. The ratio of board-feet to cubic-feet increases much more rapidly in the Doyle rule than for the Scribner and International ¼-inch. A small change in diameter can result in a large change in the board-foot to cubic-foot ratio in smaller trees, and volumes can be quite variable in young stands. As stand age increases, however, this variation decreases.

APPLICATION

One of the many potential uses for the equation system is to obtain current and projected volumes for an existing stand. For example, suppose a loblolly

Table 4.—*Evaluation of prediction equations by different criteria*

Variable	Number of observations	Criterion				
		I^2[1]	$\bar{D}$[2]	RMSE[3]	$\bar{D}\%$[4]	RMSE%[5]
			--------- *ft²* -------		----*percent*----	
Basal area:						
Merchantable	145	.90	–1.3	8.6	–1	13
Sawtimber[6]	134	.79	–1.4	11.4	0	22
			---------*ft³* -------			
Merchantable Volume	441	.94	–1	214	2	19
Sawtimber volume						
Cubic[6]	420	.96	–3	150	3	19
			--------*fbm* -------			
Doyle rule[6]	420	.85	30	1.245	22	64
Scribner rule[6]	420	.92	9	1.212	9	34
International ¼-inch rule[6]	420	.94	–1	1,255	7	28

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[1] Fit index $I^2 = 1 - \Sigma(\hat{Y}_i - Y_i)^2/\Sigma(Y_i - \bar{Y})^2$

[2] Mean difference $\bar{D} = \frac{1}{n}\Sigma(\hat{Y}_i - Y_i)$

[3] Root mean square error RMSE $= \sqrt{\frac{1}{n}\Sigma(\hat{Y}_i - Y_i)^2}$

[4] Percentage of mean difference $\bar{D}\% = \frac{1}{n}\sum\left(\frac{\hat{Y}_i - Y_i}{Y_i}\right) \times 100$

[5] Percentage of root mean square error RMSE% $= \sqrt{\frac{1}{n}\sum\left(\frac{\hat{Y}_i - Y_i}{Y_i}\right)^2} \times 100$

where n = number of observations, Y_i = observed value, $\hat{Y}_i$ = predicted value, and $\bar{Y}$ = observed mean value.

[6] Observations where $Y_i = 0$ were not used in calculating the criteria.

pine stand is 25 years old, has a merchantable basal area of 75 square feet per acre, contains 35 square feet per acre of basal area in sawtimber-sized trees, and grows on land that has a site index of 95 feet. Estimates are desired for the current stand volumes as well as what they may be in 5 years. The present volumes are

$$C_{m1} = \exp\{2.9679 + 0.010761(95) - (22.785/25) + 0.98590\ln(75)\}, = 1{,}534 \text{ cubic feet.}$$

$$C_{s1} = \exp\{3.0350 + 0.0096502(95) - (22.595/25) + 0.95222\ln(35)\}, = 622 \text{ cubic feet.}$$

$$D_1 = \exp\{4.8481 + 0.020742(95) - (45.895/25) + 0.7429\ln(35)\}, = 2{,}047 \text{ board-feet, Doyle rule.}$$

$$S_1 = \exp\{4.9716 + 0.013965(95) - (32.890/25) + 0.87555\ln(35)\}, = 3{,}280 \text{ board-feet, Scribner rule.}$$

$$I_1 = \exp\{5.0598 + 0.012151(95) - (29.448/25) + 0.91106\ln(35)\}, = 3{,}926 \text{ board-feet, International } 1/4\text{-inch rule.}$$

To obtain projected volumes at age 30, it is first necessary to predict the basal areas. Merchantable basal area at age 30 is

$$B_{m2} = \left[0.0020518/1.5662 - \left[0.0020518/1.5662 - 75^{(1-2.2332)}\right] (30/25)^{1.5662(1-2.2332)} \right]^{1/(1-2.2332)},$$

$$= 91 \text{ square feet.}$$

After merchantable basal area has been obtained, the projected sawtimber basal area may be calculated,

$$B_{s2} = 91 \left[1 - \left[1 - (35/75)^{(1-0.18171)}\right] (30/25)^{-3.0768(1-0.18171)} \right]^{1/(1-0.18171)},$$

$$= 60 \text{ square feet.}$$

Projected volumes are now determined using projected basal areas,

$$C_{m2} = \exp\{2.9679 + 0.010761(95) - (22.785/30) + 0.98590\ln(91)\}, = 2{,}160 \text{ cubic-feet.}$$

$$C_{s2} = \exp\{3.0350 + 0.0096502(95) - (22.595/30) + 0.95222\ln(60)\}, = 1{,}209 \text{ cubic-feet.}$$

$$D_2 = \exp\{4.8481 + 0.020742(95) - (45.895/30) + 0.74294\ln(60)\}, = 4{,}149 \text{ board-feet, Doyle rule.}$$

$$S_2 = \exp\{4.9716 + 0.013965(95) - (32.890/30) + 0.87555\ln(60)\}, = 6{,}547 \text{ board-feet, Scribner rule.}$$

$$I_2 = \exp\{5.0598 + 0.012151(95) - (29.448/30) + 0.91106\ln(60)\}, = 7{,}807 \text{ board-feet, International } 1/4\text{-inch rule.}$$

The periodic annual growth for merchantable volume for this example is 125 cubic-feet per acre. Sawtimber growth is 117 cubic-feet; 420 board-feet, Doyle rule; 653 board-feet, Scribner rule; and 776 board-feet, International ¼-inch rule.

The equations or tables can also be used to evaluate the probable yields that might result from adopting a certain harvesting schedule. Consider a 20-year old stand of loblolly pine which has 110 square feet of merchantable basal area per acre, 30 square feet of sawtimber basal area, and occurs on land with a site index of 90 feet. The harvest schedule under consideration is to thin periodically from below to 80 square feet of merchantable basal area and harvest the stand at age 45. The yield that might accrue from this strategy can be determined by using the tables in the appendix.

The merchantable basal areas before thinning for ages 20–45 are determined first. The merchantable basal area of 110 square feet will be reduced at age 20 to 80 square feet. The projected merchantable basal area at age 25 is determined from table 6, and it is 101 square feet per acre. The stand is thinned, and the merchantable basal area is reduced again to 80 square feet. The projected basal area at age 30 is determined; it is 97 square feet. The projected merchantable basal areas at ages 30 through 45 years are determined in a similar manner. The following tabulation can now be constructed for merchantable basal area:

Age	Before cut	After cut	Yield
years		*ft²/acre*	
20	110	80	30
25	101	80	21
30	97	80	17
35	94	80	14
40	92	80	12
45	91	. . .	91
Total			185

Projected sawtimber basal areas are calculated next. Sawtimber basal area growth depends upon merchantable basal area. It will change wherever merchantable basal area is reduced by cutting, even if no sawtimber basal area is harvested. None of the sawtimber basal area is cut at age 20, since it is not greater than 80 square feet. The projected sawtimber basal area at age 25 is found by using table 7. Given a merchantable basal area of 80 at age 20 with a sawtimber basal area of 30 square feet, the projected sawtimber density at age 25 is 64 square feet. Since it is still less than 80, no thinning in the sawtimber portion occurs. The projected basal area at age 30 of 84 square feet is found in a similar manner by using the densities at age 25 and interpolation. The sawtimber density is now reduced to 80 square feet, and projected densities for sawtimber are equal to those for merchantable basal area. Using the same procedure, the basal area at age 35 is 94 feet. The sawtimber basal areas through rotation age 45 are:

Age	Before cut	After cut	Yield
years	*ft^2/acre*		
20	30	30	
25	64	64	
30	84	80	4
35	94	80	14
40	92	80	12
45	91		91
Total			121

The volumes associated with these basal areas can now be calculated using the above figures. Merchantable cubic-foot volumes are found in table 8. Given a site index of 90 feet, age 20 years, and a merchantable basal area of 110 square feet, the merchantable volume is 1,688 cubic feet before thinning. The volume after thinning to 80 square feet is 1,233 cubic feet, and the cut is 455 cubic feet. The volumes for the other ages are found in like manner to yield the following tabulation for merchantable volumes:

Age	Before cut	After cut	Yield
years	*ft^3/acre*		
20	1,688	1,233	455
25	1,949	1,549	400
30	2,180	1,803	377
35	2,355	2,009	346
40	2,502	2,180	322
45	2,637		2,637
Total			4,537

The cubic-foot volumes harvested in sawtimber are determined from table 9 by using stand age, site index, and sawtimber basal area. Those volumes are shown in the following:

Age	Before cut	After cut	Yield
years	*ft^3/acre*		
20	408	408	
25	1,053	1,053	
30	1,587	1,515	72
35	1,967	1,687	280
40	2,089	1,829	260
45	2,201		2,201
Total			2,813

The following board-foot volumes, Doyle rule, were calculated from table 10.

Age	Before cut	After cut	Yield
years	*fbm/acre (Doyle rule)*		
20	1,040	1,040	
25	2,889	2,899	...
30	4,802	4,631	171
35	6,496	5,763	733
40	7,532	6,789	743
45	8,487		8,487
Total			10,134

The board foot volumes for the Scribner rule were found in table 11.

Age	Before cut	After cut	Harvest
years	*fbm/acre (Scribner rule)*		
20	1,923	1,923	
25	5,188	5,188	
30	8,196	7,854	342
35	10,578	9,186	1,392
40	11,675	10,331	1,344
45	12,671		12,671
Total			15,749

Finally, the board-foot volumes, International ¼-inch rule, were calculated from table 12.

Age	Before cut	After cut	Harvest
years	*fbm/acre (International ¼-inch rule)*		
20	2,392	2,392	
25	6,403	6,403	
30	9,982	9,548	434
35	12,724	10,985	1,739
40	13,860	12,204	1,656
45	14,893		14,893
Total			18,722

Average production or mean annual increment throughout the rotation may be found by dividing the total yield by the rotation age, 45 years in this case. Mean annual increment for merchantable volume for this example is 101 cubic-feet per acre per year. For the sawtimber portion the average production for the different volume measures are 63 cubic-feet; 225 board-feet, Doyle rule; 350 board-feet, Scribner rule; and 416 board-feet, International ¼-inch rule.

Yields from other management regimes can be determined by following the same procedure.

Table 5.—*Average loblolly sawtimber basal area—merchantable basal area ratio by merchantable basal area, site index, and age at initial measurement for 296 study plots*

Age	Site index	Merchantable basal area (ft^2) ≤20	21–40	41–60	61–80	81–100	101–120	121+	All basal areas
years	*feet*	*sawtimber to merchantable basal area ratio*							
≤20	≤70				0.00				0.00
	71–80	.33		.10					.24
	81–90	.37	.05		.47	.50		.23	.31
	91–100		.51	.43	.37	.30			.44
	101+	.74	.44	.30	.69	.44	.54		.49
	All sites	.48	.40	.31	.56	.37	.54	.23	.41
21–30	≤70	1.00	.69	.17	0.00	.67			.53
	71–80	.48	.46	.57	.62		.18		.49
	81–90	.67	.67	.57	.53	.73	.83		.63
	91–100	1.00	.80	.76	.68	.89	.50	.59	.72
	101+			.77	.79	.74		.83	.78
	All sites	.63	.63	.64	.63	.75	.58	.65	.64
31–40	≤70		.47		.21				.37
	71–80	.60		.68	.67	.58	1.00		.66
	81–90	1.00	.89	.78	.70	.70	.76		.78
	91–100		.62	.82	.68	.79	.55	.56	.71
	101+	1.00				.96	.93		.96
	All sites	.73	.73	.76	.63	.71	.76	.56	.71
41–50	≤70	.75	1.00	.60	.72				.73
	71–80	1.00	.67	.91					.89
	81–90	1.00	.94	.83	.90	.80			.89
	91–100			.86	.89	.95			.91
	101+			1.00	1.00	.96			.99
	All sites	.88	.90	.84	.84	.91			.86
51+	≤70	0.00	.92	1.00					.75
	71–80		.93	.77		.54			.80
	81–90	1.00	1.00		1.00	.82			.98
	91–100		1.00	.96	.97		.83		.96
	101+								
	All sites	.67	.96	.84	.98	.68	.83		.88
All ages	≤70	.62	.73	.59	.43	.33			.59
	71–80	.52	.59	.67	.66	.57	.59		.61
	81–90	.65	.74	.68	.72	.69	.78	.23	.70
	91–100	1.00	.68	.74	.72	.71	.61	.59	.70
	101+	.79	.44	.56	.79	.68	.67	.82	.63
	All sites	.63	.66	.68	.69	.65	.69	.60	.66

CONCLUSION

The user should be aware that the projected merchantable basal areas presented here do not include ingrowth that crosses the 5-inch dbh threshold. Projected values will underestimate young stands where ingrowth is a significant component of basal area growth. As stand age increases, this underestimation ceases to be a problem. However, projected sawtimber basal area does include ingrowth.

Projection and predictions made between 20 and 50 years in stand age, 20 to 100 square feet per acre of merchantable basal area, and 70 to 100 feet site index (base age 50) are well within the range of the data used in this study. Estimates outside these ranges should be used with caution, especially if merchantable densities are greater than 120 square feet per acre. Consult tables 1 and 3 for further information on the sample data ranges.

If sawtimber basal area estimates are not available for stands of interest, table 5 may be used to compute it by using stand age, site index, and merchantable basal area. The ratio of sawtimber basal area to merchantable basal area may be determined from the table and then multiplied by the observed merchantable basal area to obtain an estimate of sawtimber basal area. But, if at all possible, observed sawtimber density should be used.

The stands represented by the 296 sample plots used in this study run the gamut of conditions from managed to unmanaged stands where species other than loblolly can make up to 50 percent of the merchantable basal area. Thus the equations provide estimates of woods-run conditions. Silvicultural operations — such as precommercial thinning to achieve early spacing and density control, intermediate cutting to promote sustained growth of the residual stand, and periodic prescribed burning or application of herbicides to control competing vegetation — should boost yields beyond those reported here. Because production from managed stands should be greater, the volumes reported here provide a benchmark by which to evaluate the performance of managed stands.

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APPENDIX

Table 6.--Projected merchantable basal area by initial merchantable basal area, initial age, and final age for natural even-aged stands of loblolly pine in the West Gulf

Initial age	Final age	Initial merchantable basal area (ft^2)								
		30	40	50	60	70	80	90	100	110
----*years*----		ft^2								
20	25	41	54	66	78	90	101	112	122	132
	30	52	68	82	95	107	119	129	139	148
	35	63	81	96	110	122	134	144	153	161
	40	74	93	109	123	135	146	155	164	171
25	30	39	51	63	75	86	97	108	118	128
	35	48	62	76	88	101	112	123	133	142
	40	57	73	88	101	114	125	135	145	154
	45	66	83	99	113	125	136	146	155	163
30	35	37	49	61	72	83	94	105	115	125
	40	45	58	72	84	96	107	118	128	138
	45	52	68	82	95	107	119	129	139	148
	50	60	76	91	105	118	129	139	149	157
35	40	36	48	59	71	82	92	103	113	123
	45	43	56	69	81	92	104	114	125	134
	50	49	64	77	90	102	114	125	135	144
	55	56	71	86	99	112	123	134	143	152
40	45	35	47	58	69	80	91	101	111	122
	50	41	54	66	78	90	101	112	122	132
	55	47	61	74	87	99	110	121	131	141
	60	52	68	82	95	107	119	129	139	148
45	50	35	46	57	68	79	90	100	110	120
	55	40	52	64	76	88	99	109	120	130
	60	45	58	72	84	96	107	118	128	138
50	55	34	46	57	67	78	89	99	109	119
	60	39	51	63	75	86	97	108	118	128
55	60	34	45	56	67	77	88	98	108	119

Table 7.--Projected sawtimber basal area by initial merchantable basal area, initial age, and final age for natural even-aged stands of loblolly pine in the West Gulf

Initial age	Final age	Initial merchantable basal area	Initial sawtimber basal area (ft^2)									
			10	20	30	40	50	60	70	80	90	100
---*years*---		---*ft²*---										
20	25	30	25	33	41							
		40	30	38	46	54						
		50	34	43	51	59	66					
		60	39	47	55	63	71	78				
		70	43	51	60	67	75	82	90			
		80	47	55	64	71	79	86	94	101		
		90	51	59	67	75	83	90	97	104	112	
		100	54	63	71	79	86	93	101	108	115	122
	30	30	39	46	52							
		40	48	55	61	68						
		50	56	63	70	76	82					
		60	64	71	77	83	89	95				
		70	71	78	84	90	96	102	107			
		80	77	84	90	96	102	108	113	119		
		90	84	90	96	102	108	113	119	124	129	
		100	89	96	102	108	113	119	124	129	134	139
	35	30	52	58	63							
		40	65	70	76	81						
		50	75	81	86	91	96					
		60	85	91	96	101	105	110				
		70	94	99	104	109	114	118	122			
		80	102	107	112	116	121	125	129	134		
		90	109	114	119	123	127	132	136	140	144	
		100	115	120	125	129	133	137	141	145	149	153
	40	30	65	70	74							
		40	80	84	89	93						
		50	92	97	101	105	109					
		60	103	108	112	116	119	123				
		70	113	117	121	125	128	132	135			
		80	121	125	129	132	136	139	143	146		
		90	128	132	136	139	143	146	149	152	155	
		100	134	138	142	145	149	152	155	158	161	164
25	30	30	22	30	39							
		40	26	35	43	51						
		50	30	38	47	55	63					
		60	33	42	51	59	67	75				
		70	37	46	54	62	70	78	86			

Table 7.--Projected sawtimber basal area by initial merchantable basal area, initial age, and final age for natural even-aged stands of loblolly pine in the West Gulf (continued)

Initial age	Final age	Initial merchantable basal area	Initial sawtimber basal area (ft^2)									
			10	20	30	40	50	60	70	80	90	100
---*years*---		----------------	----------------	----------------	----------------	----------------	ft^2	----------------	----------------	----------------	----------------	----------------
25	30	80	40	49	57	66	74	81	89	97		
		90	43	52	61	69	77	85	92	100	108	
		100	46	55	64	72	80	88	95	103	110	118
	35	30	33	41	48							
		40	41	48	55	62						
		50	48	55	62	69	76					
		60	54	62	69	76	82	88				
		70	60	68	75	82	88	94	101			
		80	66	74	80	87	93	100	106	112		
		90	71	79	86	92	99	105	111	117	123	
		100	76	84	91	97	103	109	115	121	127	133
	40	30	44	51	57							
		40	55	61	67	73						
		50	64	71	77	82	88					
		60	73	79	85	91	96	101				
		70	81	87	93	98	103	109	114			
		80	88	94	100	105	110	115	120	125		
		90	94	100	106	111	116	121	126	131	135	
		100	100	106	112	117	122	127	131	136	141	145
	45	30	55	61	66							
		40	68	73	78	83						
		50	79	84	89	94	99					
		60	89	94	99	104	108	113				
		70	98	103	108	112	117	121	125			
		80	106	111	116	120	124	128	132	136		
		90	113	118	122	127	131	135	139	142	146	
		100	119	124	129	133	137	141	144	148	152	155
30	35	30	20	29	37							
		40	23	32	41	49						
		50	26	35	44	53	61					
		60	29	39	47	56	64	72				
		70	32	41	50	59	67	75	83			
		80	35	44	53	62	70	78	86	94		
		90	38	47	56	64	73	81	89	97	105	
		100	40	50	58	67	75	83	91	99	107	115
	40	30	30	37	45							
		40	36	44	51	58						
		50	42	50	57	65	72					

Table 7.--Projected sawtimber basal area by initial merchantable basal area, initial age, and final age for natural even-aged stands of loblolly pine in the West Gulf (continued)

Initial age	Final age	Initial merchantable basal area	Initial sawtimber basal area$((ft^2)$									
			10	20	30	40	50	60	70	80	90	100
---*years*---		----------------*ft²*----------------										
30	40	60	47	55	63	70	77	84				
		70	53	61	68	75	82	89	96			
		80	58	66	73	80	87	94	101	107		
		90	63	71	78	85	92	98	105	111	118	
		100	67	75	82	89	96	103	109	116	122	128
	45	30	39	46	52							
		40	48	55	61	68						
		50	56	63	70	76	82					
		60	64	71	77	83	89	95				
		70	71	78	84	90	96	102	107			
		80	77	84	90	96	102	108	113	119		
		90	84	90	96	102	108	113	119	124	129	
		100	89	96	102	108	113	119	124	129	134	139
	50	30	48	54	60							
		40	59	65	71	76						
		50	69	75	81	86	91					
		60	78	84	90	95	100	105				
		70	87	93	98	103	108	113	118			
		80	94	100	105	110	115	120	124	129		
		90	101	107	112	117	121	126	131	135	139	
		100	107	113	118	123	127	132	136	140	145	149
35	40	30	18	28	36							
		40	21	30	39	48						
		50	24	33	42	51	59					
		60	27	36	45	54	62	71				
		70	29	39	47	56	65	73	82			
		80	32	41	50	59	67	76	84	92		
		90	34	43	52	61	70	78	86	95	103	
		100	36	46	55	63	72	80	89	97	105	113
	45	30	27	35	43							
		40	32	41	48	56						
		50	38	46	54	61	69					
		60	42	51	59	66	73	81				
		70	47	56	63	71	78	85	92			
		80	52	60	68	75	83	90	97	104		
		90	56	64	72	79	87	94	101	107	114	
		100	60	68	76	83	90	98	104	111	118	125

Table 7 --Projected sawtimber basal area by initial merchantable basal area, initial age, and final age for natural even-aged stands of loblolly pine in the West Gulf (continued)

Initial age	Final age	Initial merchantable basal area	Initial sawtimber basal area (ft^2)									
			10	20	30	40	50	60	70	80	90	100
---*years*---		---ft^2---										
35	50	30	35	42	49							
		40	43	50	57	64						
		50	50	58	64	71	77					
		60	57	64	71	78	84	90				
		70	63	71	78	84	90	96	102			
		80	69	77	83	90	96	102	108	114		
		90	75	82	89	95	101	107	113	119	125	
		100	80	87	94	100	106	112	118	124	129	135
	55	30	43	49	56							
		40	53	59	66	71						
		50	62	69	75	80	86					
		60	70	77	83	89	94	99				
		70	78	84	90	96	101	107	112			
		80	85	91	97	103	108	113	118	123		
		90	91	98	103	109	114	119	124	129	134	
		100	97	103	109	114	120	124	129	134	139	143
40	45	30	17	27	35							
		40	20	29	38	47						
		50	22	32	41	49	58					
		60	25	34	43	52	61	69				
		70	27	36	45	54	63	72	80			
		80	29	39	48	56	65	74	82	91		
		90	31	41	50	59	67	76	84	93	101	
		100	33	43	52	61	69	78	86	95	103	111
	50	30	25	33	41							
		40	30	38	46	54						
		50	34	43	51	59	66					
		60	39	47	55	63	71	78				
		70	43	51	60	67	75	82	90			
		80	47	55	64	71	79	86	94	101		
		90	51	59	67	75	83	90	97	104	112	
		100	54	63	71	79	86	93	101	108	115	122
	55	30	32	40	47							
		40	39	47	54	61						
		50	46	53	60	67	74					
		60	52	59	67	74	80	87				
		70	58	65	72	79	86	92	99			
		80	63	71	78	85	91	98	104	110		

Table 7.--Projected sawtimber basal area by initial merchantable basal area, initial age, and final age for natural even-aged stands of loblolly pine in the West Gulf (continued)

Initial age	Final age	Initial merchantable basal area	Initial sawtimber basal area (ft^2)									
			10	20	30	40	50	60	70	80	90	100
---years---		---ft^2---										
40	55	90	68	76	83	90	96	102	109	115	121	
		100	73	81	88	94	101	107	113	119	125	131
	60	30	39	46	52							
		40	48	55	61	68						
		50	56	63	70	76	82					
		60	64	71	77	83	89	95				
		70	71	78	84	90	96	102	107			
		80	77	84	90	96	102	108	113	119		
		90	84	90	96	102	108	113	119	124	129	
		100	89	96	102	108	113	119	124	129	134	139
45	50	30	17	26	35							
		40	19	28	37	46						
		50	21	30	40	48	57					
		60	23	33	42	51	59	68				
		70	25	35	44	53	62	70	79			
		80	27	37	46	55	64	72	81	90		
		90	29	38	48	57	65	74	83	91	100	
		100	31	40	50	59	67	76	85	93	102	110
	55	30	23	32	40							
		40	27	36	44	52						
		50	32	40	49	57	64					
		60	36	44	53	61	69	76				
		70	39	48	56	65	72	80	88			
		80	43	52	60	68	76	84	91	99		
		90	46	55	64	72	79	87	95	102	109	
		100	50	59	67	75	83	90	98	105	112	120
	60	30	30	37	45							
		40	36	44	51	58						
		50	42	50	57	65	72					
		60	47	55	63	70	77	84				
		70	53	61	68	75	82	89	96			
		80	58	66	73	80	87	94	101	107		
		90	63	71	78	85	92	98	105	111	118	
		100	67	75	82	89	96	103	109	116	122	128
50	55	30	16	25	34							
		40	18	27	37	46						
		50	20	29	39	48	57					
		60	22	31	41	50	59	67				

Table 7.--Projected sawtimber basal area by initial merchantable basal area, initial age, and final age for natural even-aged stands of loblolly pine in the West Gulf (continued)

Initial age	Final age	Initial merchantable basal area	Initial sawtimber basal area (ft^2)									
			10	20	30	40	50	60	70	80	90	100
----*years*----		--ft^2--										
50	55	70	23	33	42	51	60	69	78			
		80	25	35	44	53	62	71	80	89		
		90	27	37	46	55	64	73	82	90	99	
		100	28	38	48	57	66	75	83	92	101	109
	60	30	22	30	39							
		40	26	35	43	51						
		50	30	38	47	55	63					
		60	33	42	51	59	67	75				
		70	37	46	54	62	70	78	86			
		80	40	49	57	66	74	81	89	97		
		90	43	52	61	69	77	85	92	100	108	
		100	46	55	64	72	80	88	95	103	110	118
55	60	30	15	25	34							
		40	17	27	36	45						
		50	19	29	38	47	56					
		60	21	30	40	49	58	67				
		70	22	32	41	50	60	68	77			
		80	24	34	43	52	61	70	79	88		
		90	25	35	45	54	63	72	81	89	98	
		100	27	37	46	55	64	73	82	91	100	108

Table 8.--Merchantable cubic-foot volume of natural even-aged stands of loblolly pine in the West Gulf given stand age, site index, and merchantable basal area

Age	Merchantable basal area	Site index *(ft)*					
		70	80	90	100	110	120
years	*ft²*	*ft³*					
20	30	378	421	469	522	581	648
	35	440	490	546	608	677	754
	40	502	559	623	693	772	860
	45	564	628	699	779	867	966
	50	626	697	776	864	962	1,072
	55	687	765	852	949	1,057	1,177
	60	749	834	929	1,034	1,152	1,283
	65	810	902	1,005	1,119	1,246	1,388
	70	872	971	1,081	1,204	1,341	1,493
	75	933	1,039	1,157	1,289	1,435	1,598
	80	994	1,107	1,233	1,373	1,529	1,703
	85	1,056	1,176	1,309	1,458	1,624	1,808
	90	1,117	1,244	1,385	1,542	1,718	1,913
	95	1,178	1,312	1,461	1,627	1,812	2,018
	100	1,239	1,380	1,537	1,711	1,906	2,122
	105	1,300	1,448	1,612	1,796	2,000	2,227
	110	1,361	1,516	1,688	1,880	2,093	2,331
25	30	475	529	589	656	730	813
	35	553	616	686	763	850	947
	40	631	702	782	871	970	1,080
	45	708	789	878	978	1,089	1,213
	50	786	875	974	1,085	1,208	1,346
	55	863	961	1,070	1,192	1,327	1,478
	60	940	1,047	1,166	1,299	1,446	1,611
	65	1,018	1,133	1,262	1,405	1,565	1,743
	70	1,095	1,219	1,358	1,512	1,684	1,875
	75	1,172	1,305	1,453	1,618	1,802	2,007
	80	1,249	1,391	1,549	1,725	1,921	2,139
	85	1,326	1,476	1,644	1,831	2,039	2,271
	90	1,403	1,562	1,739	1,937	2,157	2,402
	95	1,479	1,648	1,835	2,043	2,275	2,534
	100	1,556	1,733	1,930	2,149	2,393	2,665
	105	1,633	1,818	2,025	2,255	2,511	2,797
	110	1,710	1,904	2,120	2,361	2,629	2,928
30	30	553	616	685	763	850	947
	35	643	717	798	889	990	1,102
	40	734	817	910	1,014	1,129	1,257
	45	824	918	1,022	1,139	1,268	1,412
	50	915	1,019	1,134	1,263	1,407	1,566

Table 8.--Merchantable cubic-foot volume of natural even-aged stands of loblolly pine in the West Gulf given stand age, site index, and merchantable basal area (continued)

Age	Merchantable basal area	Site index *(ft)*					
		70	80	90	100	110	120
years	ft^2	ft^3					
30	55	1,005	1,119	1,246	1,388	1,545	1,721
	60	1,095	1,219	1,358	1,512	1,684	1,875
	65	1,185	1,319	1,469	1,636	1,822	2,029
	70	1,274	1,419	1,580	1,760	1,960	2,183
	75	1,364	1,519	1,692	1,884	2,098	2,336
	80	1,454	1,619	1,803	2,008	2,236	2,490
	85	1,543	1,719	1,914	2,131	2,373	2,643
	90	1,633	1,818	2,025	2,255	2,511	2,796
	95	1,722	1,918	2,136	2,378	2,649	2,949
	100	1,811	2,017	2,246	2,502	2,786	3,102
	105	1,901	2,117	2,357	2,625	2,923	3,255
	110	1,990	2,216	2,468	2,748	3,060	3,408
35	30	616	686	764	851	948	1,055
	35	717	799	889	991	1,103	1,228
	40	818	911	1,015	1,130	1,258	1,401
	45	919	1,023	1,140	1,269	1,413	1,574
	50	1,019	1,135	1,264	1,408	1,568	1,746
	55	1,120	1,247	1,389	1,547	1,722	1,918
	60	1,220	1,359	1,513	1,685	1,877	2,090
	65	1,320	1,470	1,637	1,824	2,031	2,261
	70	1,420	1,582	1,762	1,962	2,185	2,433
	75	1,520	1,693	1,886	2,100	2,338	2,604
	80	1,620	1,804	2,009	2,238	2,492	2,775
	85	1,720	1,916	2,133	2,376	2,646	2,946
	90	1,820	2,027	2,257	2,513	2,799	3,117
	95	1,920	2,138	2,380	2,651	2,952	3,288
	100	2,019	2,248	2,504	2,788	3,105	3,458
	105	2,119	2,359	2,627	2,926	3,258	3,628
	110	2,218	2,470	2,751	3,063	3,411	3,799
40	30	668	744	829	923	1,028	1,145
	35	778	866	965	1,074	1,197	1,333
	40	888	988	1,101	1,226	1,365	1,520
	45	997	1,110	1,236	1,377	1,533	1,707
	50	1,106	1,232	1,371	1,527	1,701	1,894
	55	1,215	1,353	1,507	1,678	1,868	2,081
	60	1,324	1,474	1,642	1,828	2,036	2,267
	65	1,432	1,595	1,776	1,978	2,203	2,453
	70	1,541	1,716	1,911	2,128	2,370	2,639
	75	1,649	1,837	2,045	2,278	2,537	2,825

Table 8.--Merchantable cubic-foot volume of natural even-aged stands of loblolly pine in the West Gulf given stand age, site index, and merchantable basal area (continued)

Age	Merchantable basal area	Site index *(ft)*					
		70	80	90	100	110	120
years	ft^2			ft^3			
40	80	1,758	1,957	2,180	2,427	2,703	3,010
	85	1,866	2,078	2,314	2,577	2,870	3,196
	90	1,974	2,198	2,448	2,726	3,036	3,381
	95	2,082	2,319	2,582	2,876	3,202	3,566
	100	2,190	2,439	2,716	3,025	3,368	3,751
	105	2,298	2,559	2,850	3,174	3,534	3,936
	110	2,406	2,679	2,984	3,323	3,700	4,121
45	30	712	793	883	983	1,095	1,219
	35	829	923	1,028	1,145	1,275	1,420
	40	945	1,053	1,173	1,306	1,454	1,619
	45	1,062	1,183	1,317	1,467	1,633	1,819
	50	1,178	1,312	1,461	1,627	1,812	2,018
	55	1,294	1,441	1,605	1,787	1,990	2,217
	60	1,410	1,570	1,749	1,947	2,169	2,415
	65	1,526	1,699	1,892	2,107	2,347	2,613
	70	1,642	1,828	2,036	2,267	2,525	2,812
	75	1,757	1,957	2,179	2,427	2,702	3,009
	80	1,873	2,085	2,322	2,586	2,880	3,207
	85	1,988	2,214	2,465	2,745	3,057	3,405
	90	2,103	2,342	2,608	2,905	3,235	3,602
	95	2,218	2,470	2,751	3,064	3,412	3,799
	100	2,333	2,598	2,894	3,222	3,589	3,996
	105	2,448	2,727	3,036	3,381	3,765	4,193
	110	2,563	2,854	3,179	3,540	3,942	4,390
50	30	749	834	929	1,034	1,152	1,283
	35	872	971	1,081	1,204	1,341	1,493
	40	995	1,108	1,233	1,374	1,530	1,703
	45	1,117	1,244	1,385	1,543	1,718	1,913
	50	1,239	1,380	1,537	1,712	1,906	2,123
	55	1,361	1,516	1,688	1,880	2,094	2,332
	60	1,483	1,652	1,840	2,049	2,281	2,541
	65	1,605	1,788	1,991	2,217	2,469	2,749
	70	1,727	1,923	2,142	2,385	2,656	2,958
	75	1,848	2,058	2,292	2,553	2,843	3,166
	80	1,970	2,194	2,443	2,720	3,029	3,374
	85	2,091	2,329	2,593	2,888	3,216	3,581
	90	2,212	2,464	2,744	3,055	3,403	3,789
	95	2,334	2,599	2,894	3,223	3,589	3,997
	100	2,455	2,733	3,044	3,390	3,775	4,204

Table 8.--Merchantable cubic-foot volume of natural even-aged stands of loblolly pine in the West Gulf given stand age, site index, and merchantable basal area (continued)

Age	Merchantable basal area	Site index *(ft)*					
		70	80	90	100	110	120
years	*ft*^{2}	*ft*^{3}					
50	105	2,576	2,868	3,194	3,557	3,961	4,411
	110	2,696	3,003	3,344	3,724	4,147	4,618
55	30	781	869	968	1,078	1,201	1,337
	35	909	1,012	1,127	1,255	1,398	1,556
	40	1,037	1,154	1,286	1,432	1,594	1,775
	45	1,164	1,297	1,444	1,608	1,791	1,994
	50	1,292	1,439	1,602	1,784	1,987	2,212
	55	1,419	1,580	1,760	1,960	2,182	2,430
	60	1,546	1,722	1,917	2,135	2,378	2,648
	65	1,673	1,863	2,075	2,311	2,573	2,865
	70	1,800	2,004	2,232	2,486	2,768	3,083
	75	1,927	2,145	2,389	2,661	2,963	3,300
	80	2,053	2,286	2,546	2,835	3,158	3,516
	85	2,180	2,427	2,703	3,010	3,352	3,733
	90	2,306	2,568	2,860	3,185	3,546	3,949
	95	2,432	2,709	3,016	3,359	3,741	4,166
	100	2,558	2,849	3,173	3,533	3,935	4,382
	105	2,684	2,989	3,329	3,707	4,129	4,598
	110	2,810	3,130	3,485	3,881	4,322	4,813
60	30	808	900	1,002	1,116	1,243	1,384
	35	941	1,048	1,167	1,299	1,447	1,611
	40	1,073	1,195	1,331	1,482	1,650	1,838
	45	1,205	1,342	1,495	1,664	1,854	2,064
	50	1,337	1,489	1,658	1,847	2,056	2,290
	55	1,469	1,636	1,822	2,029	2,259	2,516
	60	1,600	1,782	1,985	2,210	2,461	2,741
	65	1,732	1,929	2,148	2,392	2,663	2,966
	70	1,863	2,075	2,311	2,573	2,865	3,191
	75	1,994	2,221	2,473	2,754	3,067	3,416
	80	2,125	2,367	2,636	2,935	3,269	3,640
	85	2,256	2,513	2,798	3,116	3,470	3,864
	90	2,387	2,658	2,960	3,296	3,671	4,088
	95	2,518	2,804	3,122	3,477	3,872	4,312
	100	2,648	2,949	3,284	3,657	4,073	4,536
	105	2,779	3,094	3,446	3,838	4,274	4,759
	110	2,909	3,240	3,608	4,018	4,474	4,982

Table 9.--Sawtimber cubic-foot volume of natural even-aged stands of loblolly pine in the West Gulf given stand age, site index, and sawtimber basal area

Age	Sawtimber basal area	Site index *(ft)*					
		70	80	90	100	110	120
years	*ft*^{2}			*ft*^{3}			
20	10	118	130	144	158	174	192
	15	174	192	211	233	256	282
	20	229	252	278	306	337	371
	25	283	312	343	378	416	459
	30	337	371	408	450	495	546
	35	390	430	473	521	574	632
	40	443	488	537	592	652	718
	45	495	546	601	662	729	803
	50	548	603	664	732	806	887
25	10	148	163	180	198	218	240
	15	218	240	265	291	321	354
	20	287	316	348	383	422	465
	25	355	391	430	474	522	575
	30	422	465	512	564	621	684
	35	489	538	593	653	719	792
	40	555	611	673	742	817	900
	45	621	684	753	830	914	1,006
	50	687	756	833	917	1,010	1,112
	55	752	828	912	1,004	1,106	1,218
	60	817	900	991	1,091	1,202	1,323
	65	882	971	1,069	1,178	1,297	1,428
	70	946	1,042	1,147	1,264	1,392	1,533
	75	1,010	1,113	1,225	1,349	1,486	1,637
	80	1,074	1,183	1,303	1,435	1,580	1,740
30	10	172	190	209	230	254	279
	15	254	279	308	339	373	411
	20	334	367	405	446	491	540
	25	413	454	500	551	607	668
	30	491	541	595	656	722	795
	35	568	626	689	759	836	921
	40	645	711	783	862	950	1,046
	45	722	795	876	965	1,062	1,170
	50	798	879	968	1,066	1,174	1,293
	55	874	963	1,060	1,168	1,286	1,416
	60	950	1,046	1,152	1,268	1,397	1,539
	65	1,025	1,129	1,243	1,369	1,508	1,660
	70	1,100	1,211	1,334	1,469	1,618	1,782
	75	1,174	1,293	1,424	1,569	1,728	1,903
	80	1,249	1,375	1,515	1,668	1,837	2,023

Table 9.--Sawtimber cubic-foot volume of natural even-aged stands of loblolly pine in the West Gulf given stand age, site index, and sawtimber basal area (continued)

Age	Sawtimber basal area	Site index *(ft)*					
		70	80	90	100	110	120
years	*ft²*	*ft³*					
30	85	1,323	1,457	1,605	1,767	1,946	2,144
	90	1,397	1,539	1,695	1,866	2,055	2,263
35	20	371	409	451	496	547	602
	25	459	506	557	614	676	744
	30	547	602	663	730	804	885
	35	633	697	768	845	931	1,025
	40	719	792	872	960	1,057	1,165
	45	804	886	975	1,074	1,183	1,303
	50	889	979	1,078	1,187	1,308	1,440
	55	973	1,072	1,181	1,300	1,432	1,577
	60	1,057	1,165	1,283	1,413	1,556	1,713
	65	1,141	1,257	1,384	1,524	1,679	1,849
	70	1,225	1,349	1,485	1,636	1,802	1,984
	75	1,308	1,440	1,586	1,747	1,924	2,119
	80	1,391	1,532	1,687	1,858	2,046	2,253
	85	1,473	1,623	1,787	1,968	2,168	2,387
	90	1,556	1,713	1,887	2,078	2,289	2,521
	95	1,638	1,804	1,987	2,188	2,410	2,654
	100	1,720	1,894	2,086	2,298	2,530	2,787
40	30	592	653	719	791	872	960
	35	686	756	832	917	1,009	1,112
	40	779	858	945	1,041	1,146	1,262
	45	872	960	1,057	1,164	1,282	1,412
	50	964	1,061	1,169	1,287	1,418	1,561
	55	1,055	1,162	1,280	1,410	1,552	1,710
	60	1,146	1,263	1,390	1,531	1,686	1,857
	65	1,237	1,362	1,501	1,653	1,820	2,004
	70	1,328	1,462	1,610	1,773	1,953	2,151
	75	1,418	1,561	1,720	1,894	2,086	2,297
	80	1,508	1,660	1,829	2,014	2,218	2,443
	85	1,597	1,759	1,937	2,134	2,350	2,588
	90	1,687	1,857	2,046	2,253	2,481	2,732
	95	1,776	1,956	2,154	2,372	2,612	2,877
	100	1,865	2,053	2,261	2,491	2,743	3,021
	105	1,953	2,151	2,369	2,609	2,873	3,164
	110	2,042	2,249	2,476	2,727	3,004	3,308
45	30	631	695	765	843	928	1,022
	35	731	805	886	976	1,075	1,184
	40	830	914	1,006	1,108	1,221	1,344

Table 9.--Sawtimber cubic-foot volume of natural even-aged stands of loblolly pine in the West Gulf given stand age, site index, and sawtimber basal area (continued)

Age	Sawtimber basal area	Site index *(ft)*					
		70	80	90	100	110	120
years	*ft*^{2}	*ft*^{3}					
45	45	928	1,022	1,126	1,240	1,365	1,504
	50	1,026	1,130	1,245	1,371	1,509	1,662
	55	1,124	1,237	1,363	1,501	1,653	1,820
	60	1,221	1,344	1,480	1,630	1,796	1,978
	65	1,317	1,451	1,598	1,760	1,938	2,134
	70	1,414	1,557	1,715	1,888	2,080	2,290
	75	1,510	1,663	1,831	2,016	2,221	2,446
	80	1,605	1,768	1,947	2,144	2,362	2,601
	85	1,701	1,873	2,063	2,272	2,502	2,755
	90	1,796	1,978	2,178	2,399	2,642	2,909
	95	1,891	2,082	2,293	2,526	2,781	3,063
	100	1,985	2,186	2,408	2,652	2,921	3,216
	105	2,080	2,290	2,522	2,778	3,059	3,369
	110	2,174	2,394	2,637	2,904	3,198	3,522
50	40	872	961	1,058	1,165	1,283	1,413
	45	976	1,075	1,184	1,304	1,436	1,581
	50	1,079	1,188	1,309	1,441	1,587	1,748
	55	1,181	1,301	1,433	1,578	1,738	1,914
	60	1,283	1,414	1,557	1,714	1,888	2,079
	65	1,385	1,525	1,680	1,850	2,038	2,244
	70	1,486	1,637	1,803	1,985	2,187	2,408
	75	1,587	1,748	1,925	2,120	2,335	2,572
	80	1,688	1,859	2,047	2,255	2,483	2,735
	85	1,788	1,969	2,169	2,389	2,631	2,897
	90	1,888	2,080	2,290	2,522	2,778	3,059
	95	1,988	2,189	2,411	2,656	2,925	3,221
	100	2,088	2,299	2,532	2,788	3,071	3,382
	105	2,187	2,408	2,652	2,921	3,217	3,543
	110	2,286	2,517	2,773	3,053	3,363	3,703
55	40	909	1,001	1,102	1,214	1,337	1,473
	45	1,017	1,120	1,233	1,358	1,496	1,647
	50	1,124	1,238	1,363	1,502	1,654	1,821
	55	1,231	1,356	1,493	1,644	1,811	1,994
	60	1,337	1,473	1,622	1,786	1,967	2,167
	65	1,443	1,589	1,750	1,928	2,123	2,338
	70	1,549	1,706	1,878	2,069	2,278	2,509
	75	1,654	1,821	2,006	2,209	2,433	2,680
	80	1,759	1,937	2,133	2,349	2,587	2,849
	85	1,863	2,052	2,260	2,489	2,741	3,019
	90	1,967	2,167	2,386	2,628	2,894	3,188

Table 9.--Sawtimber cubic-foot volume of natural even-aged stands of loblolly pine in the West Gulf given stand age, site index, and sawtimber basal area (continued)

Age	Sawtimber basal area	Site index *(ft)*					
		70	80	90	100	110	120
years	ft^2	ft^3					
55	95	2,071	2,281	2,512	2,767	3,047	3,356
	100	2,175	2,395	2,638	2,905	3,200	3,524
	105	2,279	2,509	2,764	3,044	3,352	3,692
	110	2,382	2,623	2,889	3,181	3,504	3,859
60	40	941	1,036	1,141	1,256	1,384	1,524
	45	1,052	1,159	1,276	1,406	1,548	1,705
	50	1,163	1,281	1,411	1,554	1,711	1,885
	55	1,274	1,403	1,545	1,702	1,874	2,064
	60	1,384	1,524	1,678	1,849	2,036	2,242
	65	1,493	1,645	1,811	1,995	2,197	2,420
	70	1,603	1,765	1,944	2,141	2,358	2,597
	75	1,712	1,885	2,076	2,286	2,518	2,773
	80	1,820	2,004	2,207	2,431	2,677	2,949
	85	1,928	2,123	2,339	2,576	2,836	3,124
	90	2,036	2,242	2,469	2,720	2,995	3,299
	95	2,144	2,361	2,600	2,863	3,153	3,473
	100	2,251	2,479	2,730	3,007	3,311	3,647
	105	2,358	2,597	2,860	3,150	3,469	3,820
	110	2,465	2,714	2,989	3,292	3,626	3,993

Table 10.--Sawtimber volume, board feet (Doyle rule), of natural even-aged stands of loblolly pine in the West Gulf given stand age, site index, and sawtimber basal area

Age	Sawtimber basal area	Site index (ft)					
		70	80	90	100	110	120
years	*ft*^{2}	*fbm*					
20	10	304	374	460	566	696	857
	15	410	505	621	765	941	1,158
	20	508	625	770	947	1,165	1,434
	25	600	738	908	1,118	1,375	1,692
	30	687	845	1,040	1,280	1,575	1,938
	35	770	948	1,166	1,435	1,766	2,173
	40	851	1,047	1,288	1,585	1,950	2,399
	45	928	1,142	1,406	1,730	2,128	2,619
	50	1,004	1,235	1,520	1,870	2,302	2,832
25	10	481	591	728	895	1,102	1,356
	15	649	799	983	1,210	1,489	1,832
	20	804	990	1,218	1,498	1,844	2,269
	25	949	1,168	1,437	1,769	2,176	2,678
	30	1,087	1,337	1,646	2,025	2,492	3,066
	35	1,219	1,500	1,845	2,271	2,794	3,438
	40	1,346	1,656	2,038	2,508	3,086	3,797
	45	1,469	1,808	2,224	2,737	3,368	4,144
	50	1,589	1,955	2,405	2,960	3,642	4,482
	55	1,705	2,098	2,582	3,177	3,909	4,810
	60	1,819	2,238	2,754	3,389	4,170	5,132
	65	1,931	2,376	2,923	3,597	4,426	5,446
	70	2,040	2,510	3,089	3,800	4,676	5,754
	75	2,147	2,642	3,251	4,000	4,922	6,057
	80	2,253	2,772	3,411	4,197	5,164	6,355
30	10	653	803	988	1,216	1,496	1,841
	15	882	1,085	1,335	1,643	2,022	2,488
	20	1,092	1,344	1,654	2,035	2,504	3,081
	25	1,289	1,586	1,952	2,402	2,955	3,636
	30	1,476	1,816	2,235	2,750	3,384	4,164
	35	1,655	2,037	2,506	3,084	3,794	4,669
	40	1,828	2,249	2,767	3,405	4,190	5,156
	45	1,995	2,455	3,020	3,717	4,573	5,628
	50	2,157	2,655	3,266	4,019	4,946	6,086
	55	2,316	2,849	3,506	4,314	5,309	6,532
	60	2,470	3,040	3,740	4,602	5,663	6,969
	65	2,622	3,226	3,969	4,884	6,010	7,395
	70	2,770	3,408	4,194	5,161	6,350	7,814
	75	2,916	3,588	4,415	5,432	6,684	8,225
	80	3,059	3,764	4,631	5,699	7,013	8,629

Table 10.--Sawtimber volume, board feet (Doyle rule), of natural even-aged stands of loblolly pine in the West Gulf given stand age, site index, and sawtimber basal area (continued)

Age	Sawtimber basal area	Site index *(ft)*					
		70	80	90	100	110	120
years	ft^2	*fbm*					
30	85	3,200	3,937	4,845	5,962	7,336	9,027
	90	3,339	4,108	5,055	6,220	7,654	9,418
35	20	1,359	1,672	2,057	2,532	3,115	3,833
	25	1,604	1,974	2,428	2,988	3,677	4,525
	30	1,837	2,260	2,781	3,422	4,210	5,181
	35	2,059	2,534	3,118	3,837	4,721	5,810
	40	2,274	2,798	3,443	4,237	5,214	6,415
	45	2,482	3,054	3,758	4,625	5,691	7,002
	50	2,684	3,303	4,064	5,001	6,154	7,572
	55	2,881	3,545	4,363	5,368	6,605	8,128
	60	3,074	3,782	4,654	5,727	7,047	8,671
	65	3,262	4,014	4,939	6,077	7,478	9,202
	70	3,447	4,241	5,219	6,421	7,902	9,723
	75	3,628	4,464	5,493	6,759	8,317	10,234
	80	3,806	4,683	5,763	7,091	8,726	10,737
	85	3,981	4,899	6,028	7,418	9,128	11,232
	90	4,154	5,112	6,290	7,740	9,524	11,719
	95	4,324	5,321	6,548	8,057	9,914	12,199
	100	4,492	5,528	6,802	8,370	10,299	12,673
40	30	2,164	2,662	3,276	4,031	4,960	6,104
	35	2,426	2,985	3,674	4,520	5,562	6,844
	40	2,679	3,297	4,057	4,992	6,142	7,558
	45	2,924	3,598	4,428	5,448	6,704	8,249
	50	3,162	3,891	4,788	5,892	7,250	8,921
	55	3,394	4,177	5,140	6,324	7,782	9,576
	60	3,621	4,456	5,483	6,746	8,302	10,215
	65	3,843	4,729	5,819	7,160	8,810	10,841
	70	4,060	4,996	6,148	7,565	9,309	11,455
	75	4,274	5,259	6,471	7,963	9,798	12,057
	80	4,484	5,517	6,789	8,354	10,280	12,649
	85	4,690	5,772	7,102	8,739	10,753	13,232
	90	4,894	6,022	7,410	9,118	11,220	13,806
	95	5,095	6,269	7,714	9,492	11,680	14,372
	100	5,292	6,512	8,013	9,860	12,133	14,930
	105	5,488	6,753	8,309	10,224	12,581	15,481
	110	5,681	6,990	8,601	10,584	13,024	16,026
45	30	2,458	3,024	3,721	4,579	5,635	6,934
	35	2,756	3,391	4,173	5,135	6,319	7,775
	40	3,044	3,745	4,608	5,670	6,978	8,586

Table 10.--Sawtimber volume, board feet (Doyle rule), of natural even-aged stands of loblolly pine in the West Gulf given stand age, site index, and sawtimber basal area (continued)

Age	Sawtimber basal area	Site index (ft)					
		70	80	90	100	110	120
years	*ft*^{2}	*fbm*					
45	45	3,322	4,088	5,030	6,189	7,616	9,371
	50	3,592	4,420	5,439	6,693	8,236	10,134
	55	3,856	4,745	5,838	7,184	8,840	10,878
	60	4,113	5,062	6,228	7,664	9,430	11,604
	65	4,365	5,372	6,610	8,133	10,008	12,315
	70	4,613	5,676	6,984	8,594	10,575	13,012
	75	4,855	5,974	7,351	9,046	11,131	13,696
	80	5,094	6,268	7,712	9,490	11,677	14,369
	85	5,328	6,556	8,068	9,927	12,215	15,031
	90	5,559	6,841	8,418	10,358	12,745	15,683
	95	5,787	7,121	8,763	10,782	13,268	16,326
	100	6,012	7,398	9,103	11,201	13,783	16,960
	105	6,234	7,671	9,439	11,615	14,292	17,586
	110	6,453	7,941	9,771	12,023	14,794	18,205
50	40	3,370	4,147	5,103	6,279	7,727	9,508
	45	3,679	4,526	5,570	6,854	8,433	10,377
	50	3,978	4,895	6,023	7,412	9,120	11,222
	55	4,270	5,254	6,465	7,955	9,789	12,046
	60	4,555	5,605	6,897	8,487	10,443	12,850
	65	4,834	5,948	7,320	9,007	11,083	13,637
	70	5,108	6,285	7,734	9,516	11,710	14,409
	75	5,376	6,616	8,141	10,017	12,326	15,167
	80	5,640	6,941	8,540	10,509	12,931	15,912
	85	5,900	7,260	8,934	10,993	13,527	16,645
	90	6,156	7,575	9,321	11,470	14,114	17,367
	95	6,409	7,886	9,703	11,940	14,692	18,079
	100	6,658	8,192	10,080	12,404	15,263	18,781
	105	6,903	8,494	10,452	12,862	15,826	19,474
	110	7,146	8,793	10,820	13,314	16,383	20,159
55	40	3,664	4,508	5,547	6,826	8,399	10,335
	45	3,999	4,920	6,054	7,450	9,167	11,280
	50	4,324	5,321	6,547	8,057	9,914	12,199
	55	4,642	5,711	7,028	8,648	10,641	13,094
	60	4,951	6,093	7,497	9,225	11,352	13,968
	65	5,255	6,466	7,957	9,790	12,047	14,824
	70	5,552	6,832	8,407	10,345	12,729	15,663
	75	5,844	7,191	8,849	10,889	13,399	16,487
	80	6,131	7,545	9,284	11,424	14,057	17,297
	85	6,414	7,892	9,711	11,950	14,704	18,094
	90	6,692	8,235	10,133	12,468	15,342	18,878

Table 10.--Sawtimber volume, board feet (Doyle rule), of natural even-aged stands of loblolly pine in the West Gulf given stand age, site index, and sawtimber basal area (continued)

Age	Sawtimber basal area	Site index *(ft)*					
		70	80	90	100	110	120
years	*ft²*	*fbm*					
55	95	6,966	8,572	10,548	12,979	15,971	19,652
	100	7,237	8,905	10,958	13,483	16,591	20,416
	105	7,504	9,234	11,362	13,981	17,204	21,169
	110	7,768	9,558	11,762	14,473	17,809	21,914
60	40	3,927	4,833	5,947	7,317	9,004	11,079
	45	4,287	5,275	6,490	7,986	9,827	12,093
	50	4,636	5,704	7,019	8,637	10,628	13,077
	55	4,976	6,123	7,534	9,270	11,407	14,037
	60	5,308	6,532	8,037	9,890	12,169	14,974
	65	5,633	6,932	8,529	10,496	12,915	15,892
	70	5,952	7,324	9,012	11,090	13,646	16,791
	75	6,265	7,709	9,486	11,673	14,363	17,674
	80	6,573	8,088	9,952	12,246	15,069	18,542
	85	6,876	8,461	10,411	12,810	15,763	19,396
	90	7,174	8,828	10,862	13,366	16,447	20,238
	95	7,468	9,189	11,307	13,914	17,121	21,067
	100	7,758	9,546	11,747	14,454	17,786	21,886
	105	8,044	9,899	12,180	14,988	18,443	22,694
	110	8,327	10,247	12,609	15,515	19,091	23,492

Table 11.--Sawtimber volume, board feet (Scribner rule), of natural even-aged stands of loblolly pine in the West Gulf given stand age, site index, and sawtimber basal area

Age	Sawtimber basal area	Site index *(ft)*					
		70	80	90	100	110	120
years	*ft*^{2}			*fbm*			
20	10	556	639	735	845	972	1,118
	15	793	912	1,048	1,205	1,386	1,594
	20	1,020	1,173	1,349	1,551	1,783	2,050
	25	1,240	1,426	1,640	1,885	2,168	2,493
	30	1,455	1,673	1,923	2,212	2,543	2,924
	35	1,665	1,914	2,201	2,531	2,911	3,347
	40	1,871	2,152	2,474	2,845	3,272	3,762
	45	2,075	2,386	2,743	3,154	3,627	4,171
	50	2,275	2,616	3,008	3,459	3,978	4,574
25	10	772	888	1,021	1,174	1,350	1,553
	15	1,102	1,267	1,457	1,675	1,926	2,215
	20	1,417	1,630	1,874	2,155	2,478	2,849
	25	1,723	1,981	2,278	2,620	3,012	3,464
	30	2,021	2,324	2,672	3,073	3,534	4,063
	35	2,313	2,660	3,059	3,517	4,044	4,650
	40	2,600	2,990	3,438	3,953	4,546	5,227
	45	2,883	3,315	3,811	4,383	5,040	5,795
	50	3,161	3,635	4,180	4,806	5,527	6,355
	55	3,436	3,951	4,544	5,225	6,008	6,908
	60	3,708	4,264	4,903	5,638	6,483	7,455
	65	3,978	4,574	5,259	6,047	6,954	7,996
	70	4,244	4,880	5,612	6,453	7,420	8,532
	75	4,509	5,184	5,961	6,855	7,882	9,063
	80	4,771	5,486	6,308	7,253	8,340	9,590
30	10	962	1,106	1,272	1,462	1,682	1,934
	15	1,372	1,577	1,814	2,086	2,398	2,758
	20	1,765	2,029	2,333	2,683	3,085	3,547
	25	2,145	2,467	2,837	3,262	3,751	4,313
	30	2,517	2,894	3,328	3,826	4,400	5,059
	35	2,880	3,312	3,809	4,379	5,036	5,790
	40	3,238	3,723	4,281	4,922	5,660	6,509
	45	3,589	4,127	4,746	5,457	6,275	7,216
	50	3,936	4,526	5,205	5,985	6,881	7,913
	55	4,279	4,920	5,657	6,505	7,480	8,601
	60	4,618	5,310	6,105	7,020	8,073	9,282
	65	4,953	5,695	6,549	7,530	8,659	9,956
	70	5,285	6,077	6,988	8,035	9,239	10,624
	75	5,614	6,455	7,423	8,535	9,814	11,285
	80	5,940	6,830	7,854	9,031	10,385	11,941

Table 11.--Sawtimber volume, board feet (Scribner rule), of natural even-aged stands of loblolly pine in the West Gulf given stand age, site index, and sawtimber basal area (continued)

Age	Sawtimber basal area	Site index *(ft)*					
		70	80	90	100	110	120
years	*ft²*	*fbm*					
30	85	6,264	7,203	8,282	9,524	10,951	12,592
	90	6,585	7,572	8,707	10,012	11,513	13,238
35	20	2,064	2,373	2,729	3,138	3,608	4,149
	25	2,509	2,885	3,318	3,815	4,387	5,044
	30	2,943	3,385	3,892	4,475	5,146	5,917
	35	3,369	3,874	4,454	5,122	5,889	6,772
	40	3,787	4,354	5,007	5,757	6,620	7,612
	45	4,198	4,827	5,551	6,382	7,339	8,439
	50	4,604	5,294	6,087	6,999	8,048	9,254
	55	5,004	5,754	6,617	7,608	8,749	10,060
	60	5,400	6,210	7,141	8,211	9,441	10,856
	65	5,793	6,661	7,659	8,807	10,127	11,644
	70	6,181	7,107	8,172	9,397	10,805	12,425
	75	6,566	7,550	8,681	9,982	11,478	13,199
	80	6,947	7,989	9,186	10,563	12,146	13,966
	85	7,326	8,424	9,687	11,138	12,808	14,727
	90	7,702	8,856	10,184	11,710	13,465	15,483
	95	8,075	9,286	10,677	12,278	14,118	16,234
	100	8,446	9,712	11,168	12,842	14,766	16,979
40	30	3,310	3,807	4,377	5,033	5,787	6,655
	35	3,789	4,357	5,009	5,760	6,624	7,616
	40	4,259	4,897	5,631	6,475	7,445	8,561
	45	4,721	5,429	6,242	7,178	8,254	9,491
	50	5,177	5,953	6,846	7,872	9,051	10,408
	55	5,628	6,472	7,441	8,557	9,839	11,314
	60	6,074	6,984	8,031	9,234	10,618	12,209
	65	6,514	7,491	8,613	9,904	11,389	13,096
	70	6,951	7,993	9,191	10,568	12,152	13,974
	75	7,384	8,491	9,763	11,226	12,909	14,844
	80	7,813	8,984	10,331	11,879	13,659	15,707
	85	8,239	9,474	10,894	12,527	14,404	16,563
	90	8,662	9,960	11,453	13,169	15,143	17,413
	95	9,082	10,443	12,008	13,808	15,877	18,257
	100	9,499	10,923	12,560	14,442	16,607	19,095
	105	9,914	11,400	13,108	15,072	17,331	19,929
	110	10,326	11,873	13,653	15,699	18,052	20,757
45	30	3,627	4,171	4,796	5,514	6,341	7,291
	35	4,151	4,773	5,489	6,311	7,257	8,345
	40	4,666	5,365	6,169	7,094	8,157	9,380

Table 11.--Sawtimber volume, board feet (Scribner rule), of natural even-aged stands of loblolly pine in the West Gulf given stand age, site index, and sawtimber basal area (continued)

Age	Sawtimber basal area	Site index *(ft)*					
		70	80	90	100	110	120
years	*ft*^{2}	*fbm*					
45	45	5,173	5,948	6,840	7,865	9,043	10,399
	50	5,673	6,523	7,501	8,625	9,917	11,404
	55	6,166	7,091	8,153	9,375	10,780	12,396
	60	6,655	7,652	8,799	10,117	11,634	13,377
	65	7,138	8,207	9,437	10,852	12,478	14,348
	70	7,616	8,758	10,070	11,579	13,315	15,310
	75	8,090	9,303	10,697	12,300	14,144	16,264
	80	8,561	9,844	11,319	13,015	14,966	17,209
	85	9,027	10,380	11,936	13,725	15,782	18,147
	90	9,491	10,913	12,549	14,429	16,592	19,079
	95	9,951	11,442	13,157	15,129	17,396	20,003
	100	10,408	11,968	13,761	15,824	18,195	20,922
	105	10,862	12,490	14,362	16,514	18,989	21,835
	110	11,314	13,009	14,959	17,201	19,779	22,743
50	40	5,020	5,772	6,637	7,632	8,776	10,091
	45	5,565	6,399	7,358	8,461	9,729	11,187
	50	6,103	7,018	8,069	9,279	10,669	12,268
	55	6,634	7,628	8,772	10,086	11,598	13,336
	60	7,159	8,232	9,466	10,885	12,516	14,392
	65	7,679	8,830	10,153	11,675	13,424	15,436
	70	8,194	9,422	10,834	12,457	14,324	16,471
	75	8,704	10,008	11,508	13,233	15,216	17,497
	80	9,210	10,590	12,177	14,002	16,101	18,514
	85	9,712	11,168	12,841	14,766	16,979	19,523
	90	10,210	11,741	13,500	15,523	17,850	20,525
	95	10,705	12,310	14,155	16,276	18,715	21,520
	100	11,197	12,875	14,805	17,024	19,575	22,509
	105	11,686	13,437	15,451	17,767	20,429	23,491
	110	12,172	13,996	16,093	18,505	21,279	24,468
55	40	5,329	6,128	7,046	8,102	9,317	10,713
	45	5,908	6,794	7,812	8,982	10,329	11,877
	50	6,479	7,450	8,567	9,850	11,327	13,024
	55	7,043	8,098	9,312	10,708	12,313	14,158
	60	7,600	8,739	10,049	11,555	13,287	15,279
	65	8,152	9,374	10,779	12,394	14,252	16,388
	70	8,699	10,002	11,501	13,225	15,207	17,486
	75	9,240	10,625	12,218	14,049	16,154	18,575
	80	9,777	11,243	12,928	14,865	17,093	19,655
	85	10,310	11,856	13,633	15,676	18,025	20,726
	90	10,840	12,464	14,332	16,480	18,950	21,790

Table 11.--Sawtimber volume, board feet (Scribner rule), of natural even-aged stands of loblolly pine in the West Gulf given stand age, site index, and sawtimber basal area (continued)

Age	Sawtimber basal area	Site index *(ft)*					
		70	80	90	100	110	120
years	*ft*^{2}	*fbm*					
55	95	11,365	13,068	15,027	17,279	19,869	22,846
	100	11,887	13,669	15,717	18,073	20,781	23,896
	105	12,406	14,265	16,403	18,861	21,688	24,939
	110	12,922	14,858	17,085	19,646	22,590	25,975
60	40	5,601	6,441	7,406	8,516	9,793	11,260
	45	6,210	7,141	8,211	9,441	10,856	12,483
	50	6,810	7,831	9,004	10,354	11,905	13,690
	55	7,403	8,512	9,788	11,255	12,942	14,881
	60	7,989	9,186	10,563	12,146	13,966	16,059
	65	8,569	9,853	11,330	13,028	14,980	17,225
	70	9,143	10,513	12,089	13,901	15,984	18,380
	75	9,712	11,168	12,842	14,766	16,979	19,524
	80	10,277	11,817	13,588	15,625	17,967	20,659
	85	10,837	12,461	14,329	16,477	18,946	21,785
	90	11,393	13,101	15,064	17,322	19,918	22,903
	95	11,946	13,736	15,795	18,162	20,884	24,014
	100	12,494	14,367	16,520	18,996	21,843	25,117
	105	13,040	14,994	17,241	19,825	22,796	26,213
	110	13,582	15,617	17,958	20,649	23,744	27,303

Table 12.—Sawtimber volume, board feet (International 1/4-inch rule) of natural even-aged stands of loblolly pine in the West Gulf given stand age, site index, and sawtimber basal area

Age	Sawtimber basal area	Site index *(ft)*					
		70	80	90	100	110	120
years	*ft*^{2}	*fbm*					
20	10	689	778	879	993	1,121	1,266
	15	997	1,126	1,272	1,436	1,622	1,831
	20	1,296	1,464	1,653	1,866	2,108	2,380
	25	1,589	1,794	2,026	2,287	2,583	2,916
	30	1,876	2,118	2,392	2,701	3,049	3,443
	35	2,158	2,437	2,752	3,108	3,509	3,963
	40	2,438	2,753	3,108	3,510	3,963	4,475
	45	2,714	3,064	3,460	3,907	4,412	4,982
	50	2,987	3,373	3,809	4,301	4,857	5,484
25	10	925	1,045	1,180	1,332	1,505	1,699
	15	1,339	1,512	1,707	1,928	2,177	2,458
	20	1,740	1,965	2,219	2,506	2,829	3,195
	25	2,132	2,408	2,719	3,070	3,467	3,915
	30	2,518	2,843	3,210	3,625	4,094	4,623
	35	2,897	3,272	3,695	4,172	4,711	5,320
	40	3,272	3,695	4,172	4,712	5,320	6,008
	45	3,643	4,114	4,645	5,245	5,923	6,688
	50	4,010	4,528	5,113	5,774	6,520	7,362
	55	4,374	4,939	5,577	6,297	7,111	8,030
	60	4,735	5,346	6,037	6,817	7,698	8,692
	65	5,093	5,751	6,494	7,333	8,280	9,350
	70	5,448	6,152	6,947	7,845	8,858	10,003
	75	5,802	6,552	7,398	8,354	9,433	10,652
	80	6,153	6,948	7,846	8,860	10,004	11,297
30	10	1,126	1,272	1,436	1,621	1,831	2,068
	15	1,629	1,840	2,078	2,346	2,649	2,991
	20	2,118	2,391	2,700	3,049	3,443	3,888
	25	2,595	2,930	3,309	3,736	4,219	4,764
	30	3,064	3,460	3,907	4,412	4,982	5,625
	35	3,526	3,982	4,496	5,077	5,733	6,473
	40	3,982	4,497	5,078	5,734	6,474	7,311
	45	4,433	5,006	5,653	6,383	7,208	8,139
	50	4,880	5,510	6,222	7,026	7,934	8,959
	55	5,322	6,010	6,787	7,663	8,654	9,772
	60	5,762	6,506	7,347	8,296	9,368	10,578
	65	6,197	6,998	7,902	8,923	10,076	11,378
	70	6,630	7,487	8,454	9,547	10,780	12,173
	75	7,060	7,973	9,003	10,166	11,479	12,962
	80	7,488	8,455	9,548	10,782	12,175	13,747

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Table 12.--Sawtimber volume, board feet (International 1/4-inch rule) of natural even-aged stands of loblolly pine in the West Gulf given stand age, site index, and sawtimber basal area (continued)

Age	Sawtimber basal area	Site index *(ft)*					
		70	80	90	100	110	120
years	*ft*^{2}	*fbm*					
30	85	7,913	8,936	10,090	11,394	12,866	14,528
	90	8,336	9,413	10,629	12,003	13,554	15,305
35	20	2,436	2,751	3,107	3,508	3,961	4,473
	25	2,986	3,371	3,807	4,299	4,854	5,482
	30	3,525	3,981	4,495	5,076	5,732	6,472
	35	4,057	4,581	5,173	5,841	6,596	7,448
	40	4,582	5,173	5,842	6,597	7,449	8,411
	45	5,101	5,760	6,504	7,344	8,293	9,364
	50	5,614	6,340	7,159	8,084	9,128	10,308
	55	6,124	6,915	7,808	8,817	9,956	11,243
	60	6,629	7,485	8,452	9,545	10,778	12,170
	65	7,130	8,052	9,092	10,267	11,593	13,091
	70	7,628	8,614	9,727	10,984	12,403	14,005
	75	8,123	9,173	10,358	11,696	13,207	14,914
	80	8,615	9,728	10,985	12,405	14,007	15,817
	85	9,104	10,281	11,609	13,109	14,803	16,715
	90	9,591	10,830	12,230	13,810	15,594	17,609
	95	10,075	11,377	12,847	14,507	16,381	18,498
	100	10,557	11,921	13,462	15,201	17,165	19,383
40	30	3,916	4,422	4,993	5,639	6,367	7,190
	35	4,507	5,089	5,746	6,489	7,327	8,274
	40	5,090	5,747	6,490	7,328	8,275	9,344
	45	5,666	6,398	7,225	8,158	9,212	10,403
	50	6,237	7,043	7,953	8,980	10,141	11,451
	55	6,803	7,682	8,674	9,795	11,060	12,489
	60	7,364	8,315	9,390	10,603	11,973	13,520
	65	7,921	8,945	10,100	11,405	12,879	14,543
	70	8,474	9,569	10,806	12,202	13,778	15,558
	75	9,024	10,190	11,507	12,993	14,672	16,568
	80	9,571	10,807	12,204	13,780	15,561	17,571
	85	10,114	11,421	12,897	14,563	16,444	18,569
	90	10,655	12,031	13,586	15,341	17,323	19,561
	95	11,193	12,639	14,272	16,116	18,198	20,549
	100	11,728	13,244	14,955	16,887	19,069	21,532
	105	12,261	13,846	15,634	17,654	19,935	22,511
	110	12,792	14,445	16,311	18,419	20,798	23,486
45	30	4,250	4,799	5,419	6,119	6,910	7,803
	35	4,891	5,523	6,236	7,042	7,952	8,979
	40	5,523	6,237	7,043	7,953	8,980	10,141

Table 12.--Sawtimber volume, board feet (International 1/4-inch rule) of natural even-aged stands of loblolly pine in the West Gulf given stand age, site index, and sawtimber basal area (continued)

Age	Sawtimber basal area	Site index (ft)					
		70	80	90	100	110	120
years	ft^2	fbm					
45	45	6,149	6,944	7,841	8,854	9,998	11,289
	50	6,769	7,643	8,631	9,746	11,005	12,427
	55	7,383	8,337	9,414	10,630	12,003	13,554
	60	7,992	9,024	10,190	11,507	12,993	14,672
	65	8,596	9,707	10,961	12,377	13,976	15,782
	70	9,197	10,385	11,727	13,242	14,953	16,885
	75	9,793	11,059	12,487	14,101	15,923	17,980
	80	10,386	11,728	13,244	14,955	16,887	19,069
	85	10,976	12,394	13,996	15,804	17,846	20,152
	90	11,563	13,057	14,744	16,649	18,800	21,229
	95	12,147	13,716	15,488	17,489	19,749	22,301
	100	12,728	14,372	16,229	18,326	20,694	23,368
	105	13,306	15,026	16,967	19,159	21,635	24,430
	110	13,883	15,676	17,702	19,989	22,571	25,487
50	40	5,897	6,659	7,519	8,491	9,588	10,826
	45	6,565	7,413	8,371	9,453	10,674	12,053
	50	7,226	8,160	9,214	10,405	11,749	13,267
	55	7,882	8,900	10,050	11,349	12,815	14,471
	60	8,532	9,635	10,879	12,285	13,872	15,665
	65	9,178	10,363	11,702	13,214	14,922	16,850
	70	9,819	11,087	12,520	14,137	15,964	18,026
	75	10,456	11,807	13,332	15,054	17,000	19,196
	80	11,089	12,522	14,139	15,966	18,029	20,358
	85	11,719	13,233	14,942	16,873	19,053	21,514
	90	12,345	13,940	15,741	17,775	20,071	22,665
	95	12,968	14,644	16,536	18,672	21,085	23,809
	100	13,589	15,344	17,327	19,566	22,093	24,948
	105	14,206	16,042	18,114	20,455	23,098	26,082
	110	14,821	16,736	18,899	21,340	24,098	27,211
55	40	6,221	7,025	7,933	8,958	10,115	11,422
	45	6,926	7,821	8,831	9,972	11,261	12,716
	50	7,624	8,609	9,721	10,977	12,395	13,997
	55	8,315	9,390	10,603	11,973	13,520	15,267
	60	9,001	10,164	11,478	12,961	14,635	16,526
	65	9,682	10,933	12,346	13,941	15,742	17,776
	70	10,359	11,697	13,208	14,915	16,842	19,018
	75	11,031	12,456	14,065	15,882	17,935	20,252
	80	11,699	13,210	14,917	16,844	19,021	21,478
	85	12,363	13,960	15,764	17,801	20,101	22,698
	90	13,024	14,707	16,607	18,752	21,175	23,911

Table 12.--Sawtimber volume, board feet (International 1/4-inch rule) of natural even-aged stands of loblolly pine in the West Gulf given stand age, site index, and sawtimber basal area (continued)

Age	Sawtimber basal area	Site index (ft)					
		70	80	90	100	110	120
years	*ft^2*	*fbm*					
55	95	13,682	15,449	17,445	19,699	22,244	25,118
	100	14,336	16,188	18,280	20,642	23,309	26,320
	105	14,988	16,924	19,111	21,580	24,368	27,516
	110	15,637	17,657	19,938	22,514	25,423	28,708
60	40	6,505	7,346	8,295	9,366	10,577	11,943
	45	7,242	8,178	9,234	10,427	11,775	13,296
	50	7,972	9,002	10,165	11,478	12,961	14,636
	55	8,695	9,818	11,087	12,519	14,137	15,963
	60	9,412	10,628	12,001	13,552	15,303	17,280
	65	10,124	11,432	12,909	14,577	16,461	18,587
	70	10,831	12,231	13,811	15,595	17,610	19,886
	75	11,534	13,024	14,707	16,607	18,753	21,176
	80	12,233	13,813	15,598	17,613	19,889	22,458
	85	12,927	14,597	16,483	18,613	21,018	23,733
	90	13,618	15,378	17,365	19,608	22,141	25,002
	95	14,306	16,154	18,241	20,598	23,259	26,265
	100	14,990	16,927	19,114	21,584	24,372	27,521
	105	15,672	17,696	19,983	22,565	25,480	28,772
	110	16,350	18,463	20,848	23,541	26,583	30,018

Murphy, Paul A. Merchantable and sawtimber volumes for natural even-aged stands of loblolly pine in the West Gulf region. Res. Pap. SO-194. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1983, 38 p.

Equations are presented for estimating merchantable and sawtimber volumes for natural even-aged stands of loblolly pine on the West Gulf Coastal Plain for woods-run conditions.

Keywords: *Pinus taeda* L., mathematical models, statistical analysis, basal area, cubic-foot volume, board-foot volume.

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Sound Can Detect Decay in Standing Hardwood Trees

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F. I. McCracken and S. R. Vann

SUMMARY

Three standing hardwood tree species, with and without heart rot, were tested for responses to sound waves to detect and estimate decay. Decay in cottonwood (*Populus deltoides*), green ash (*Fraxinus pennsylvanica*), and willow oak (*Quercus phellos*) was detected when a continuous magnetic vibrator was used at 100 Hz and 1 KHz. Signal amplitudes were greater when decay was present. Results suggest that equipment refinement could permit estimates of decay diameter. The decay was also detected by increased transit time of a 150 KHz and 54 KHz pulse signal using a James V-meter. Transit time readings differed in incipient and advanced decay. The approximate diameter of the decay column in green ash and willow oak can be determined in stems greater than 20 cm diameter.

Sound Can Detect Decay in Standing Hardwood Trees

F. I. McCracken and S. R. Vann

INTRODUCTION

Butt decay occurs in an estimated 40 percent of southern hardwood trees (McCracken 1974). Extent of that decay has been difficult to verify without cutting the timber. A nondestructive method for determining decay in standing trees would help managers select cuts, improve stands, make better sales, estimate volume losses, and identify hazardous trees in urban or high-use areas.

The need to detect decay in standing trees has prompted various methods based on different concepts. Sounding a tree by striking it with a tool can be used to detect advanced decay or hollows in standing trees, although this method was ineffective on large thick-barked trees (Boyce 1948). The transmission of gamma radiation through stems of standing trees has been used to detect and estimate decay (Filer 1970). An electrical probe inserted in a small hole drilled in stems or timbers to measure electrical resistance will indicate stages of decay (Shigo and Shigo 1974). An ultrasonic test originally developed to detect structural defects in concrete (Leslie and Cheesman 1949) has been used to test wood products for strength and defects (McDonald 1978). Sound, coupled with electronic measuring equipment, has potential as a nondestructive method to detect and estimate decay in standing hardwood trees. This study evaluates this concept.

METHODS AND MATERIALS

Conducting experiments required modifying and integrating a variety of electronic and mechanical devices. The basic item was a square wave pulse generator which provided frequencies from 10 Hz to 100 KHz. The signal was amplified by a 125-watt audio unit to power a 3×5-cm vibrator, consisting of an electromagnet within a cylindrical permanent magnet with a metal diaphragm over one end. A receiver to detect the sound was made by replacing the needle of a phonograph cartridge with a 0.5 g brass weight and firmly setting the cartridge within a 2.5×7.6-cm aluminum tube. Metal screws (14×4 mm) permanently fixed to the vibrator and receiver, were used to attach the devices to the trees during testing. The receiver was connected to an oscilloscope with a 1-watt amplifier in the line. All circuits were connected with 75 ohm coaxial cable. Power for field operation was provided by two 12-volt, lead-acid batteries, which were charged daily to maintain maximum efficiency. A 12-volt DC to 120-volt AC inverter powered the signal generator and oscilloscope. Signal responses to 100 Hz and 1 KHz, as seen on the oscilloscope during testing, were photographed. Components of the continuous vibrator system were placed in a case for field use (fig. 1).

The V-meter Model C 490z of James Instruments, Inc., an ultrasonic system for testing various building materials, was also tested for detecting decay. The transit times in microseconds (μs) of pulse signals using standard and exponential 54 KHz transducers and 150 KHz transducers were compared.

Three hardwood species of merchantable size, willow oak (*Quercus phellos* L.) 26–47 cm dbh (diameter breast height), green ash (*Fraxinus pennsylvanica* Marsh.) 21–43 cm dbh, and cottonwood (*Populus deltoides* Bartr.) 34–57 cm dbh, were chosen to represent a variety of wood types. Eight trees of each – in pairs of similar size, one with known decay and one without — were selected for testing.

The response readings were taken from cardinal directions at vertical positions marked at 30 cm intervals above ground to a height of 3 m. The tree bark was reduced by a spade bit in an electric drill to 1 mm thickness in a 5 cm diameter flat area at each sample point.

Trees were cut following field observations and a 10 cm thick disk removed at each of the vertical measurement locations. The diameter of the stem, sound wood, and decayed wood were measured on each disk, along with moisture content and specific gravity (Heinricks and Lassen 1970).

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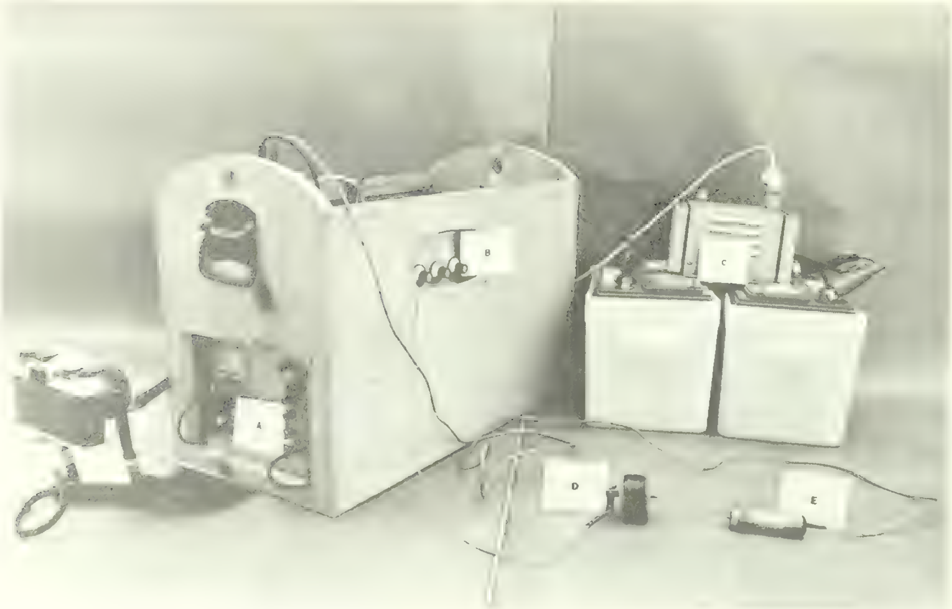

Figure 1.—*Continuous vibrator system components used to sound trees with low frequency vibrations: (A) square wave generator and oscilloscope; (B) amplifiers; (C) power supply; (D) vibrator, and (E) receiver.*

RESULTS AND DISCUSSION

Decay in standing willow oak, green ash, and cottonwood was detected with the continuous vibrator system at 100 Hz and 1 KHz, but not at 10 Hz, 10 KHz, or 100 KHz. The signal amplitude was greater from trees with decay than those without, whereas signal vs. time was similar in all types of stems (figs. 2, 3, and 4). In some trees a direct correlation appeared between amplitude and the diameter of decay, but in others it was too variable to draw conclusions. Signal amplitude was greater in stems having 5 cm or wider voids in the decay column (fig. 3D). The amplitudes of signals from green ash (fig. 2) and cottonwood (fig. 3) were similar to each other, and were greater than those from willow oak (fig. 4).

The continuous vibrator system shows promise as a tool for detecting and estimating the amount of decay, even though the system is presently impractical. Modifications and simplification of the existing model should provide an efficient model for general use.

Improvements needed are: (1) a compact, amplified, fixed frequency signal generator; (2) measurement of voltage variations of signal amplitude directly to eliminate the oscilloscope; and (3) a larger vibrator to eliminate the receiver to oscilloscope amplifier.

A direct relationship existed between the diameter of healthy stems and the transit time using the James V-meter with the 150 KHz and 54 KHz transducers. The slopes of the regression lines were similar for all three species, but the intercepts for cottonwood were greater than for the other two species (figs. 5, 6, and 7). The 150 KHz transducers were effective only on stems to about 30 cm diameter. The 54 KHz transducers produced readings on the largest stems sampled, 58 cm diameter, and the exponential 54 KHz receiver usually produced the most consistent results as indicated by the higher r^2 values (figs. 5, 6, and 7). The mean transit

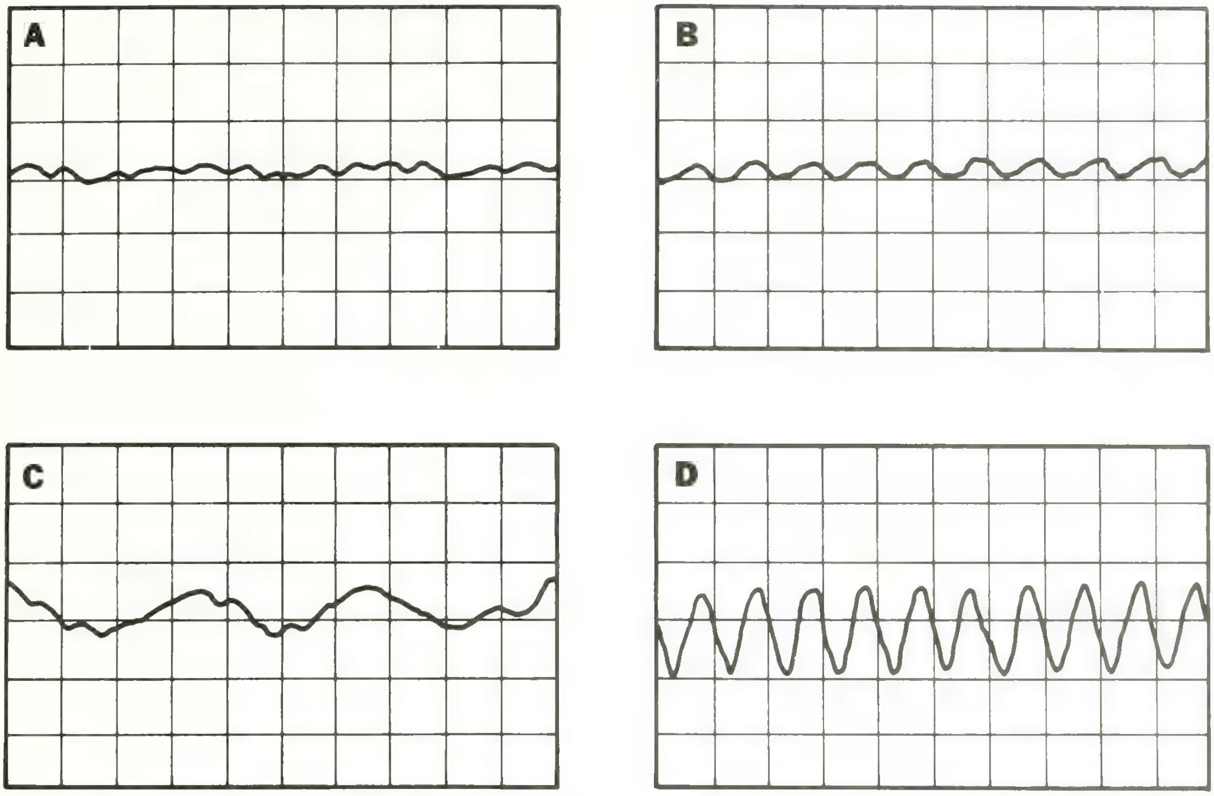

Figure 2.—*Oscilloscope response to vibrations of standing* P. deltoides *stems 33 cm diameter: (A) 100 Hz, without decay; (B) 1 KHz, without decay; (C) 100 Hz, with 8–20 cm dia decay; (D) 1 KHz, with 8–20 cm dia decay. Oscilloscope units equal 0.1 volts vertical and 0.001 seconds horizontal.*

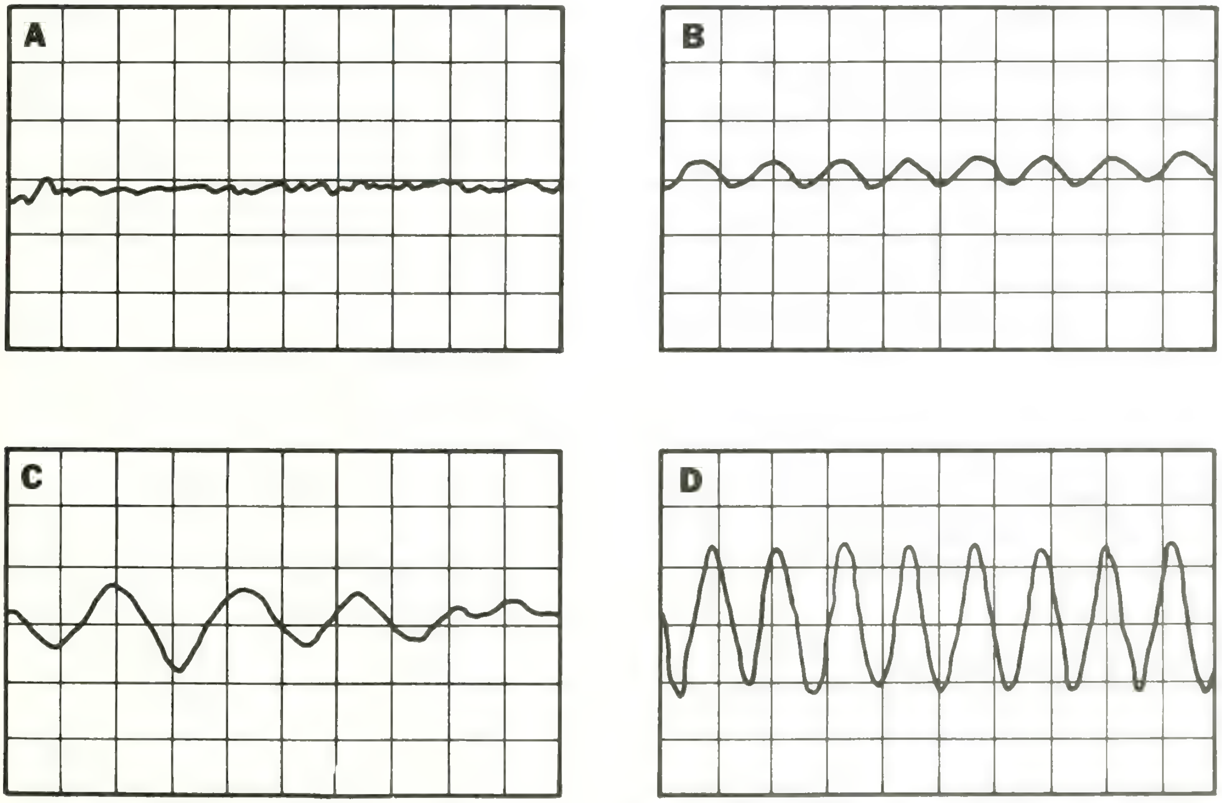

Figure 3.—*Oscilloscope response to vibration of standing* F. pennsylvanica *stems 25–27 dia: (A) 100 Hz, without decay; (B) 1 KHz, without decay; (C) 100 Hz, 20 cm dia decay; (D) 1 KHz, 20 cm dia decay. Oscilloscope units equal 0.1 volts vertical and 0.001 seconds horizontal.*

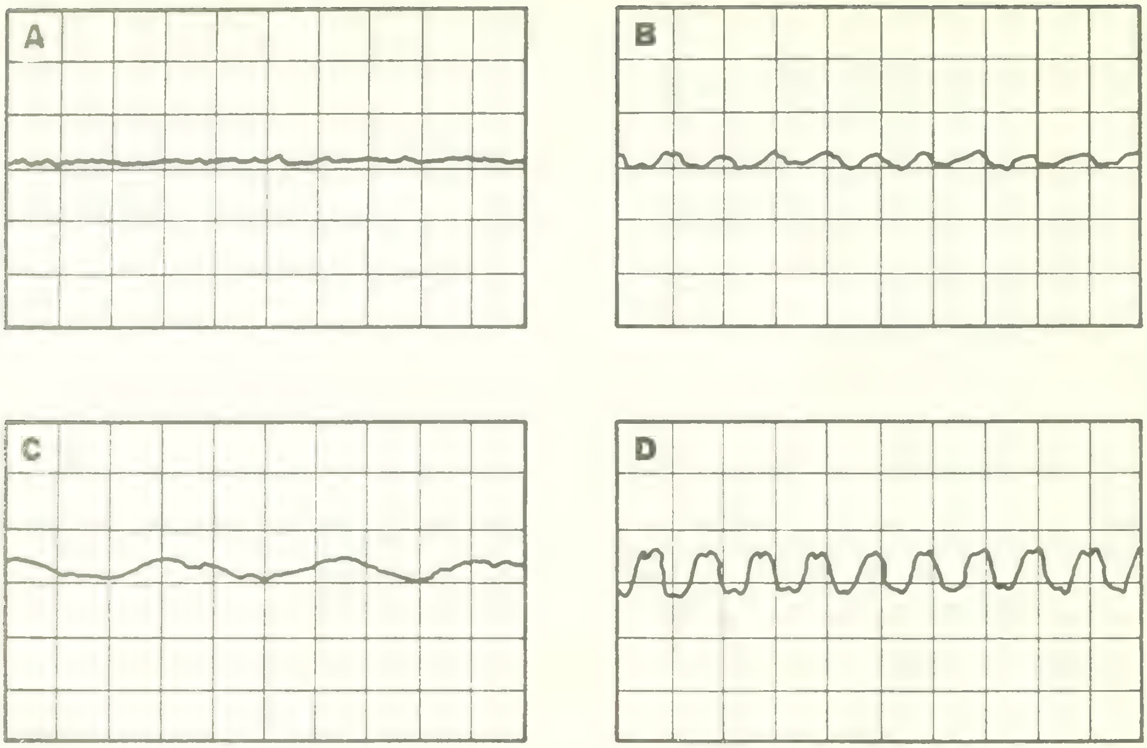

Figure 4.—*Oscilloscope response to vibration of standing* Q. phellos *stems 33–35 cm dia: (A) 100 Hz, without decay; (B) 1 KHz without decay; (C) 100 Hz, 20–23 cm dia decay; (D) 1 KHz, 20–23 cm dia decay. Oscilloscope units equal 0.1 volts vertical and 0.001 seconds horizontal.*

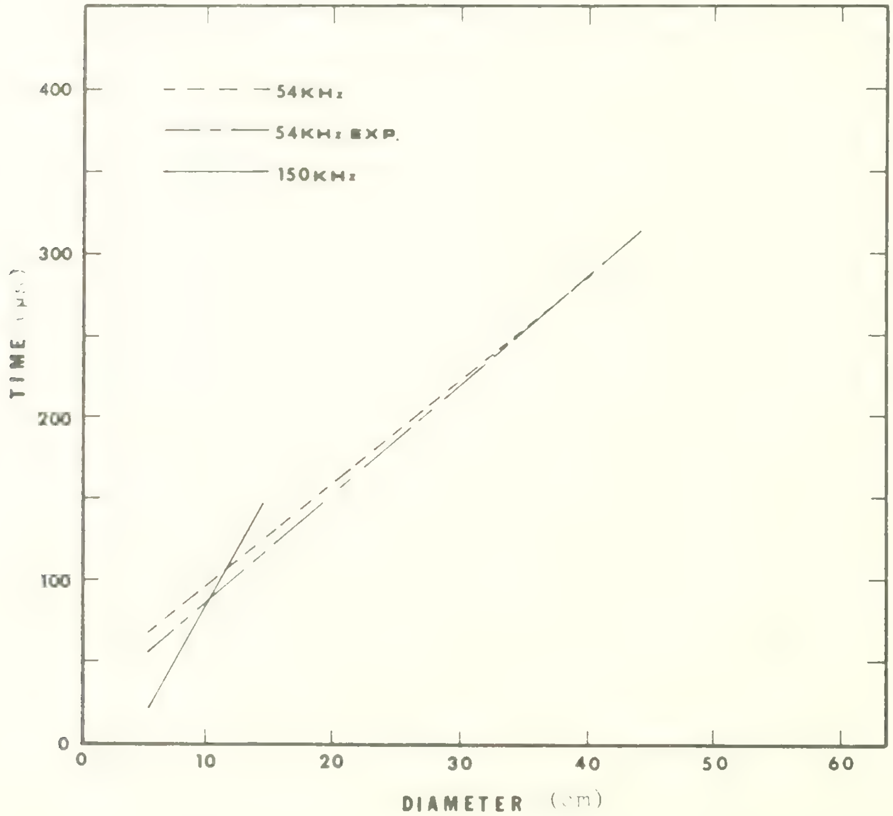

Figure 5.—*Predicted transit time (μs) of ultrasonic pulses in* P. deltoides *stems of (d) diameter without decay, using the James V-meter with three transducers. The regression equations are 54 KHz,* $\mu s = 35.79 + 15.84\ (d)$, $r^2 = 0.57$; *54 KHz exponential (Exp.).* $\mu s = 22.76 + 16.71\ (d)$, $r^2 = 0.60$; *and 150 KHz,* $\mu s = -46.27 + 34.34\ (d)$, $r^2 = 0.69$. *Attempts to meter stems with decay produced an over signal (no data).*

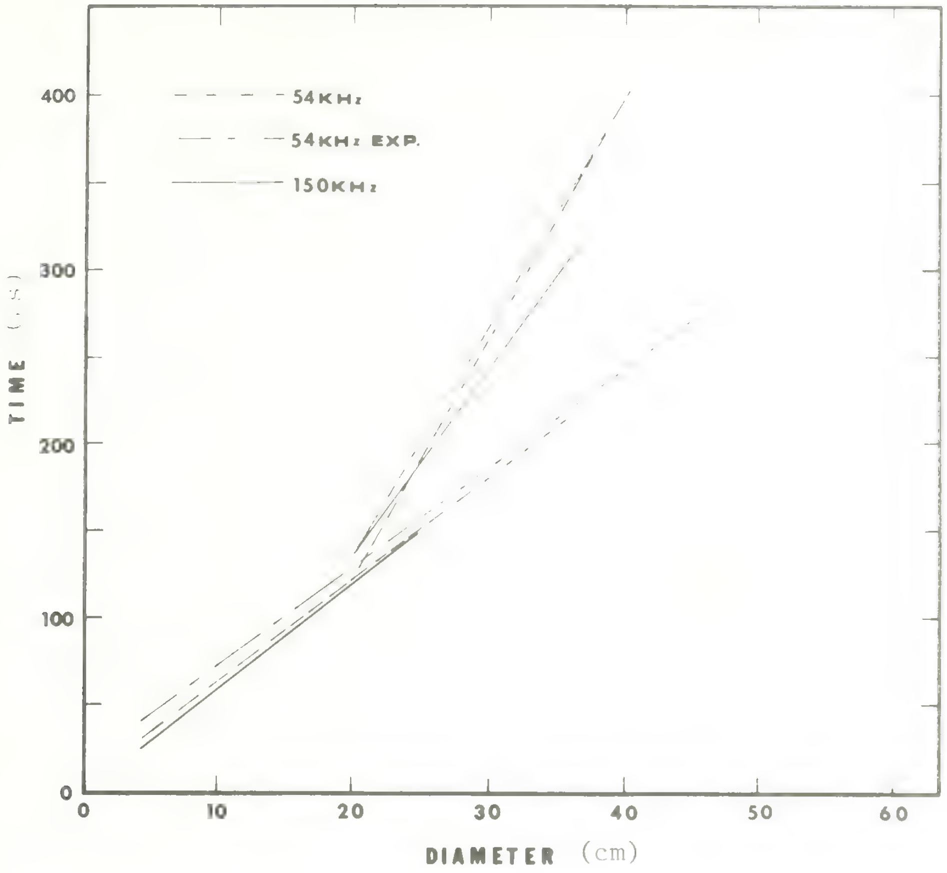

Figure 6.—*Predicted transit time* (μs) *of ultrasonic pulses in* F. pennsylvanica *stems of* (*d*) *diameter without decay, lower set of lines and stems with decay, upper set of lines. The regression equations for stems without decay are 54 KHz,* $\mu s = 6.02 + 14.76\ (d)$, $r^2 = 0.98$; *54 KHz exponential (Exp.),* $\mu s = 19.35 + 14.16\ (d)$, $r^2 = 0.94$; *150 KHz,* $\mu s = 1.48 + 15.32\ (d)$, $r^2 = 0.97$. *The regression equations for stems with decay are 54 KHz,* $\mu s = -127.98 + 33.01\ (d)$, $r^2 = 0.57$; *54 KHz Exp.,* $\mu s = -160.35 + 35.32\ (d)$, $r^2 = 0.74$; *150 KHz,* $\mu s = -76.84 + 27.15\ (d)$, $r^2 = 0.39$.

time, using the 54 KHz exponential transducer, was 6.2 μs/cm in non-decayed green ash and oak and 7.2 μs/cm in cottonwood. Transit times were unaffected by variations in moisture content and specific gravity of the samples, but wood altered by decay resulted in increased transit times in all species.

Decay in cottonwood produced inconsistent and high, 350 μs-oversignal, readings with all transducers. Decay in green ash and willow oak stems, greater than 20 cm diameter, always increased the transit time; however, consistent readings were obtained with the 54 KHz transducers.

Transit times in decayed wood varied as much as 10 μs/cm in incipient decay to 25 μs/cm in advanced decay; thus reliable estimates of the decay column diameter were impractical. However, the presence of decay and the approximate diameter of the decay column can be determined with the 54 KHz ultrasonic pulse signal of the James V-meter by comparing sample data with that presented in figures 6 and 7.

The method of coupling the transducers to the tree needs improvement. Reducing the bark in a 50–60 mm diameter tree to a thin layer greatly reduces variability in transit time readings, but this troublesome procedure can result in damaging wounds to the trees. Bark reduction or removal in a 4–5 mm diameter area, as required for the 54 KHz exponential transducer, would reduce wound size and facilitate the use of the James V-meter in detecting decay in standing trees.

Decay in standing cottonwood, green ash and willow oak can be detected reliably using the lower (54 KHz) ultrasonic pulse signal of the James V-meter. However, the diameter of the decay column cannot always be determined, since the transit time is affected by the variable condition of the decayed wood as well as the amount of decayed wood.

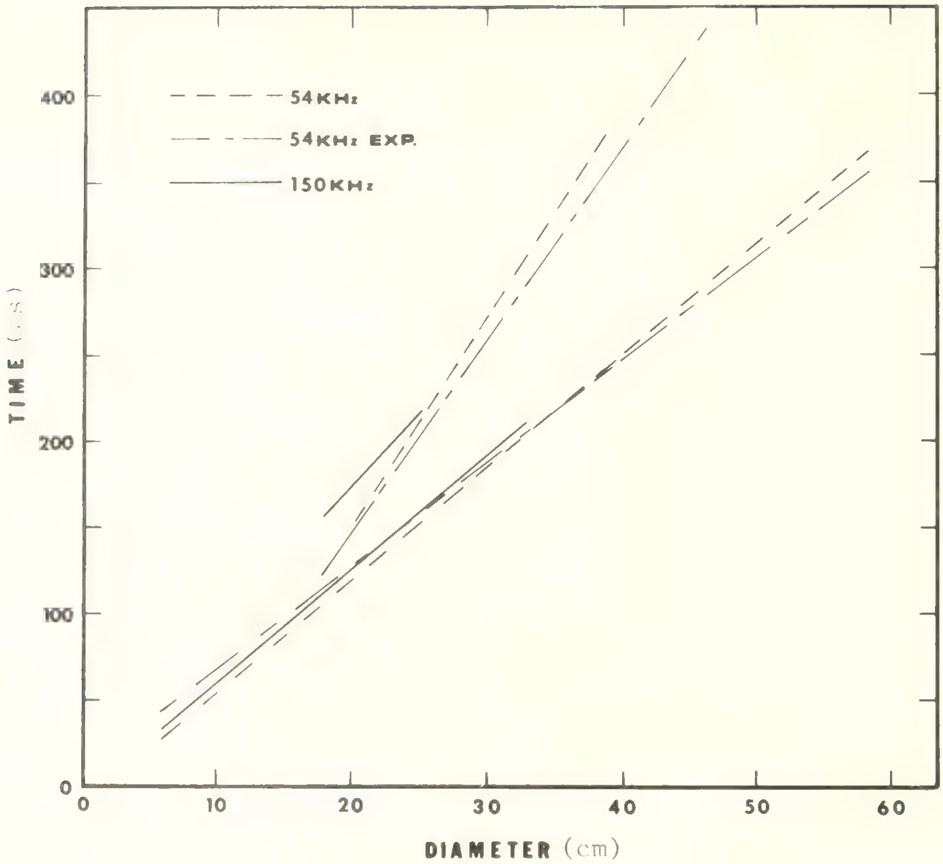

Figure 7.—*Predicted transit time (μs) of ultrasonic pulses in* Q. phellos *stems of (d) diameter without decay, lower set of lines, and stems with decay, upper set of lines. The regression equations for stems without decay are 54 KHz,* $\mu s = -10.52 + 16.42\ (d), r^2 = 0.92$; *54 KHz exponential (Exp.),* $\mu s = 7.42 + 15.06\ (d), r^2 = 0.95$; *150 KHz,* $\mu s = -0.73 + 16.09\ (d), r^2 = 0.83$. *The regression equations for stems with decay are: 54 KHz,* $\mu s = -91.15 + 30.51\ (d)\ r^2 = 0.59$; *54 KHz Exp.,* $\mu s = -69.61 + 27.58\ (d)\ r^2 = 0.72$; *150 KHz,* $\mu s = 10.12 + 20.88\ (d), r^2 = 0.21$.

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Three standing hardwood tree species, with and without heart rot, were tested for responses to sound waves to detect and estimate decay. Decay in cottonwood (*Populus deltoides*), green ash (*Fraxinus pennsylvanica*), and willow oak (*Quercus phellos*) was detected when a continuous magnetic vibrator was used at 100 Hz and 1 KHz.

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Research Note

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Water Tupelo in the Atchafalaya Basin Does Not Benefit from Thinning

Harvey E. Kennedy, Jr.

SUMMARY

Water tupelo occurs on about 4 million acres in the South and Southeast. Its wood is exceptionally clear and defect-free and is used primarily for veneer and box lumber. Most stands are dense, stagnated, and appear to need thinning or some other type stand improvement work. But in a typical stand in the Atchafalaya Basin residual trees showed no significant growth response to thinning. Reasons could be age of stand, small live crown ratio, and yearly defoliation by the forest tent caterpillar. Greatest benefit from thinning is probably salvage of trees that would otherwise be lost through mortality.

Additional keywords: *Nyssa aquatica*, wetlands, flooding, growth, volume.

INTRODUCTION

Water tupelo (*Nyssa aquatica* L.) grows most commonly in swamplands and bottomlands along watercourses in the South and Southeast. It normally grows in even-aged dense stands with or without cypress (*Taxodium distichum* (L.) Rich) and other tupelos. The wood is exceptionally clear and defect-free and is used primarily for veneer and box lumber. Small dimension trees are used for crossties and pulpwood.

Water tupelo typically has a long, clean bole strongly buttressed at the base. Trees are cut near the top of the butt swell, which may be as much as 8 feet aboveground, or they are felled and bucked to leave the basal wood. Laundrie and McKnight (1969) reported that bleached kraft and neutral sulfite semichemical pulps made from butt swells of water tupelo were well suited for manufacture of greaseproof papers and a good quality corrugating medium.

There are about 4 million acres of water tupelo in the South and Southeast. Most of this acreage is dense, stagnated, and appears to need thinning or some type of stand improvement work. Growth rates are usually low. This paper reports on the growth response of water tupelo to four thinning intensities in a typical stand in the Atchafalaya Basin. The results are probably applicable over most of the area where water tupelo is found.

METHODS

The stand was fairly uniform and well stocked except for remnants of some old pullboat roads used in logging the virgin cypress and tupelo. It is typical of forests found on thousands of acres of swampland in the South and Southeast (fig. 1). When the study was started in 1967, stand basal area was about 250 square feet per acre; trees averaged about 13 inches in diameter above the butt swell and 65 feet in height. Two crown classes, codominant and suppressed, were represented although most trees were codominant.

The individual crop-tree approach was used. Forty codominant trees, which normally should be left as crop trees during thinning, were randomly selected. One of the following treatments was randomly assigned to each:

1. Check—no thinning.
2. Light thinning—measure out 10 feet on each side from center of sample tree and cut all trees within the 20- × 20-foot square.
3. Medium thinning—same as light thinning, except measure out 15 feet from center of sample tree.
4. Heavy thinning—same as light thinning, except measure out 20 feet from center of sample tree.

These thinnings would leave about 109, 48, and 27 trees per acre, respectively. Individual tree thinning treatments appear open to question by some, but our data are sound and similar to those reported by McGarity (1979).

After treatments were assigned, trees to be removed were marked and diameter of each measured at a point above the butt swell. This was considered to be where diameter of merchantable stem would be measured—about 6–7 feet above ground line. These were used to calculate basal area removed around each tree. Stand age was determined by representative ring counts.

Study trees were marked so diameter measurements could be made at the same location each time. Measurements of diameter above the butt swell, total height, merchantable height, crown width, and live crown ratio were made when the study was installed, and at the end of 5 and 12 growing seasons.

Diameter measurements were made on 30 cut trees at 1 and 4 feet above groundline, then up every 4 feet to a 4-inch outside bark diameter. Total tree height and length of butt swell were also measured. Cubic-foot volumes in butt swell, merchantable stem, and total tree were calculated using Smalian's formula. Percent volume in butt swell in each tree was computed using the ratio of volume in butt swell to volume in total tree.

A completely randomized design with 10 replications of each treatment was used for the study. Analysis of variance using a completely randomized design was used to test differences between treatments at the 0.05 level of significance.

RESULTS AND DISCUSSION

Ring counts on cut trees showed the stand to be about 55 years old (table 1). An average of four trees and 2 square feet of basal area was removed around each tree in the light thinning treatment, nine trees and 5.6 square feet of basal area in the medium thinning, and 16 trees and 10 square feet of basal area in the heavy thinning.

Figure 1.—*Typical water tupelo stand similar to the study area.*

Thinning intensity had no significant effect on diameter growth, total height, or merchantable height. Diameters increased by 1.7, 1.4, 1.5, and 1.1 inches in the check, light, medium, and heavy thinning treatments, respectively, during the 12 years of this study. Heights increased by 6, 9, 8, and 9 feet, respectively.

Thinning intensity did significantly affect changes in crown area. Trees in the medium thinning treatment had a significantly larger crown change than the heavy thinning, with no difference between the check and light thinning. This is unusual as normally a larger increase in crown size in the heavier thinning would be expected. By treatment, 40 percent of the trees in check plots decreased in crown area over the 12 years, none in the light, 30 percent in the medium, and 40 percent in the heavy. Crown area decrease may be because of death of branches in the lower crown.

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Table 1.—*Average diameters above butt swell, total and merchantable heights, crown widths, and percent live crown by treatment and date*

	Check			10×10			15×15			20×20		
Measurement	1967	1972	1979	1967	1972	1979	1967	1972	1979	1967	1972	1979
Total height (*ft.*)	66	72	72	65	73	74	66	72	74	65	71	74
Diameter (*in.*)	13.0	14.4	14.7	13.9	14.8	15.3	13.7	14.5	15.2	13.6	14.6	14.7
Merch. height (*ft.*)	51	57	57	53	55	56	53	56	58	51	56	59
Crown width (*ft.*)	15×17	18×18	16×15	14×17	17×19	18×18	15×17	18×19	18×19	15×16	17×19	14×16
Live crown (%)	23	21	23	20	23	24	22	22	22	22	20	18

Live crown ratios averaged about 20–22 percent throughout the study period. The live crown is probably too small a proportion of the tree to respond to thinning. A general rule is to keep at least half of the tree in live crown for best growth.

Typically, water tupelo is cut near the top of the butt swell, which may be as much as 8 feet above ground, or they are cut low and bucked to leave the butt swell portion. Measurements on cut trees in this study showed that from 30–68 percent of the total cubic foot volume was in the butt swell, with an average of 47 percent of the total volume left when the butt swell portion was not used.

SUMMARY AND CONCLUSIONS

Trees showed no significant response to thinning in this stand. Reasons could be twofold: (1) trees were too old and the live crown ratio (20–22 percent) was too low before thinning, and (2) the stand was defoliated each year of the study by the forest tent caterpillar (*Malacosoma disstria* Hubner). Forest tent caterpillar defoliation each year may be a key to the lack of response. Morris (1975) reported that studies in Alabama showed 5-year growth losses of 70 percent or more in tupelos defoliated each year. Equal losses were estimated for trees in Louisiana. Morris reported that trees do not usually die when repeatedly defoliated but cannot grow. Within a month after feeding stops, new, stunted leaves appear. But these merely maintain life until the next season when the cycle is repeated.

McGarity (1979) reported on 10-year results from thinning and clearcutting in a cypress-tupelo swamp. However, because of within-replication differences of tree size, stocking, and species distribution, only a simple arithmetical summary was presented. From the 10-year growth data, it appears that McGarity's results are similar to this study except possibly in the control plot.

An average of 47 percent of the total tree cubic foot volume in this study is left in the woods if the butt swell is not utilized. But, this wood is suitable for manufacture of greaseproof paper and corrugating medium.

Results of this study indicate that even heavy thinning in water tupelo may not increase growth on the residual trees. The greatest benefit from thinning may be the salvage of trees that might otherwise die and the resultant increase in recoverable yield over the rotation of the stand.

Logging problems in a tupelo swamp require that substantial volume be removed or, more likely, clearcutting be done to justify the expense. It is possible that thinning may not be economically feasible even if a growth response is expected.

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Research Note

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A Vacuum-Aspirator for Counting Termites

Susan C. Jones and Joe K. Mauldin

SUMMARY

An aspirator-system powered by a vacuum cleaner is described for manually counting termites. It is significantly faster and termite survival is at least as high as when using a mouth-aspirator for counting large numbers of termites.

Keywords: Vacuum-aspirator, termites.

INTRODUCTION

Termites can be reliably counted in a relatively short time using an aspirator in which the suction is created by a small electric vacuum cleaner (Sears® SPV,[2] 110 volt). To minimize noise levels, the vacuum cleaner is placed outside the building and connected to the working area via rigid PVC pipe (2.5 cm inner diameter). The end of a tee connector is left open to reduce the vacuum to an acceptable level. The vacuum can be further minimized by drilling small holes in the PVC pipe. Caution should be taken to reduce the vacuum to a level so as not to injure termites.

A section of PVC pipe is positioned along the back of a work table to form a manifold into which several aspirators can be inserted and used at the same time (fig. 1). One section of a Nalgene® quick-

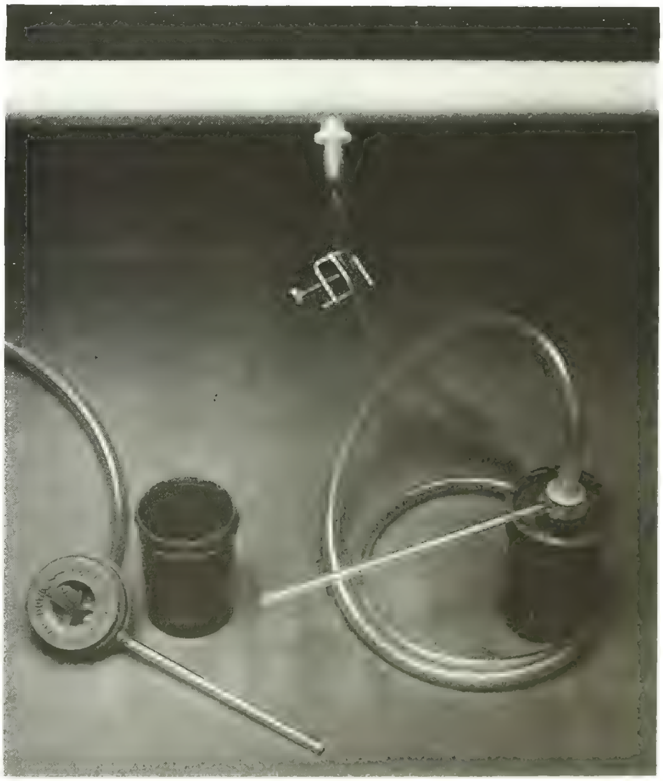

Figure 1.—*Vacuum manifold with aspirators for counting subterranean termites.*

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disconnect tubing connector is fitted in each hole drilled at intervals along the pipe. Aspirators, similarly fitted with connectors, then are hooked up to the manifold by appropriate lengths of Tygon® tubing.

Aspirators, modified 30-dr plastic pill containers, are fitted with a pick-up nozzle and vacuum connector. The nozzle is made from a 20-cm length of 6 mm (outer diameter) glass tubing bent at right angles approximately 5 cm from one end. This end is heated and forced through the center of the plastic container lid. The tubing connector is inserted through a hole drilled next to the glass tube in the cap. A small piece of copper screen is heated and secured over the interior opening of the tubing connector to prevent termites and debris from being drawn out of the container. Silicon caulking compound is useful for sealing leaks in the cap. Adjustable clamps on each piece of Tygon® tubing will regulate the vacuum to each aspirator.

The dimensions given for the vacuum system are appropriate for counting subterranean termites (*Reticulitermes* spp. and *Coptotermes formosanus* Shirraki) as they are aspirated. For other types of insects, the system might be modified by adjusting the vacuum and tubing diameters.

The methods were compared by timing how long it took to count five replicates of 100 *Reticulitermes flavipes* (Kollar) workers from each of three colonies. Termites were placed on wood and moist sand, and survival was determined after either 1, 2, 3, or 4 weeks. The vacuum-system method was significantly faster than, and percent termite survival (square root transformation) was at least as high as, the mouth-aspirator method (F-test, $P < 0.05$).

Members of our laboratory routinely use this vacuum aspirator system to count large numbers of termites. Advantages over a mouth-aspirator include operator safety and the capability for counting large numbers of termites over long periods of time. Continuous use of a mouth-aspirator often results in sore lips and occasionally an infected throat.

Those who contributed ideas to the design and construction of aspirator systems leading to the current one include: John Tynes, Kenneth Tynes, Alton Gipson, Carley Baxter, Eldon Mallette, Nely Rich, and Rubien Yates.

Susan C. Jones is Associate Entomologist and Joe K. Mauldin is Principal Entomologist, Southern Forest Experiment Station, USDA Forest Service, Gulfport, Mississippi. Mention of a company or trade name is for identification purposes only and does not imply endorsement by the U.S. Department of Agriculture.

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Research Note

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Effect of Cut-And-Leave and Cut-And-Top Control Treatments on Within-Tree Southern Pine Beetle Populations

G. D. Hertel and H. N. Wallace

SUMMARY

Effects of the cut-and-leave and cut-and-top treatments on within-tree populations of the southern pine beetle were evaluated in seven active infestations in central Louisiana. Beetle populations were significantly reduced only in December by felling freshly attacked trees.

Additional keywords: Control, sampling, *Dendroctonus frontalis* Zimmermann.

INTRODUCTION

In 1970, at the height of the most recent outbreak of the southern pine beetle (SPB) (*Dendroctonus frontalis* Zimmermann), the pest was found on more than half the region's pine land. Records show that 8.5 million cords and 2.5 million board feet of beetle-damaged pine timber were salvaged from 1960 through 1978. This timber has been valued at $200 million (Price and Doggett 1978). It was estimated that only one-third to one-half of the beetle-affected timber was salvaged.

Currently, four suppression methods for SPB are recommended: (1) salvage removal, (2) cut-and-spray, (3) pile-and-burn, and (4) cut-and-leave. A fifth method, cut-and-top, has had limited use in Texas. Salvage removal is the most widely used of these methods. Often inclement weather conditions, administrative delay of sales, low volumes of timber, inaccessibility of spots, or a poor timber market severely limits the effectiveness of the salvage removal programs. During such times, the other suppression methods offer advantages.

Two alternatives that are relatively easy to apply are cut-and-leave and cut-and-top. It has been shown that cut-and-leave reduces SPB population survival (Ollieu 1969), disrupts natural aggregation behavior (Gara 1967), promotes dispersal, and reduces subsequent tree mortality (Billings and Pase 1979).

The cut-and-leave treatment involves felling all infested trees into an opening created by dead "black- and red-topped" trees. This usually results in a large pile of infested trees. When the crowns are left intact, the inner bark (phloem) moisture is naturally dissipated through transpiration.

The cut-and-top procedure is applied in the same way as cut-and-leave, except that the tops are severed from the bole. Proponents of the procedure believe that removing the top in the winter prevents transpiration and thus maintains abnormally high moisture levels that adversely affect developing broods.

In both the cut-and-leave and cut-and-top methods, a buffer strip of green pines (equal in width to the height of infested trees) is cut in front of recently attacked trees to prevent further attacks on adjacent trees (Coster and Johnson 1979). The disruption of the natural pheromone source apparently encourages beetles to disperse at a time when they may not be physiologically ready to do so (Hedden and Billings 1977).

This note describes the influence of cut-and-leave and cut-and-top on beetle numbers.

METHODS

From 1975 to 1976, evaluations were conducted in Louisiana to determine the effect of the cut-and-leave and cut-and-top treatments on beetle numbers.

The study areas were in the Catahoula and Evangeline Ranger Districts of the Kisatchie National Forest, located in Grant and Rapides Parishes. All trees were loblolly pines (*Pinus taeda* L.) and ranged in diameter from 13 to 48 cm. Treatments were started on November 1, 1975, and ended on September 10, 1976. Seven separate spots were located and treated. In all cases, the cut-and-leave and cut-and-top trees were felled and exposed to full sunlight. The standing untreated trees were shaded on all sides, and none of the residual vegetation was removed. Treated and untreated trees were located within the same group of infested trees (spot).

The population sampling techniques and equipment used for taking the 100-cm^2 bark samples were similar to those reported by Coulson et al. (1975). The first set of bark samples was taken on the first day of treatment, prior to tree felling, from all the infested trees in that spot. Two sample disks (north and south) were collected at 1.4 m intervals, starting 1.4 m from the ground, along the infested bole. The cut-and-leave and cut-and-top trees were immediately cut after sampling and exposed to full sunlight. A second set of bark samples was taken just prior to beetle emergence. Two samples at each sampling interval (1.4 m) were taken on each untreated tree, and four samples were taken at each sampling interval from the cut-and-leave and cut-and-top trees. These samples were incubated in rearing cups for 30 days to collect emerging adults.

Total numbers of insects on each tree for each sample date were estimated by the topological mapping technique (Pulley et al. 1976). Two variables were analyzed — survival and numbers of offspring per attacking adult. A one-way analysis of variance was performed using the actual data to conduct a multiple range test on the treatment differences. A two-way analysis of variance was done for the survival data. Duncan's Multiple Range Test was used to determine if pairs of plots were significantly different from each other.

RESULTS AND DISCUSSION

Survival

For trees with late brood stages (large larvae, pupae, callow adults), there were no significant differences ($P > 0.05$) in survival among treatments, dates, and treatment by date interactions. Survival means for different treatments were variable throughout the year. Table 1 presents average beetle survival by treatment and date. Overall averages show that the two treatments reduced survival 11 and 15 percent over survival in the untreated trees. However, survival in the untreated trees was greatest for only three of the five dates.

In cut-and-top trees, average beetle survival ranged from 8 to 46 percent. The largest survival percentages, in March and September, reflect a majority of pupae and callow adults in the study trees as compared to other treatment months, December and August, when primarily larvae were present. Beetle survival in untreated trees in July (32 percent) was similar to the July results (34 percent) of Palmer and Coster (1978).

Palmer and Coster found July survival in cut-and-leave trees to be 17 percent compared to this evaluation's 18 percent. In this evaluation, cut-and-leave beetle survival ranged from 13 to 52 percent. The high (September) and low (December) seasonal values in beetle survival were comparable to the findings of Hodges and Thatcher (1976), which had been completed 1 year prior to the present evaluation.

Cut-and-leave resulted in the lowest average survival for all seasons. Average survival was 24 percent for cut-and-leave, 28 percent for cut-and-top, and 39 percent for controls (table 1). This compares to the results of Hodges and Thatcher (1976), where survival was 32, 17, and 35 percent for cut-and-leave, cut-and-top, and untreated trees, respectively.

Number of Offspring

Instead of survival, the number of offspring per attacking adult was compared in the trees containing recent attacks. In this set of experiments, there were significant differences ($p < 0.05$) in offspring for treatments within treatment dates (table 2).

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Table 1.—*Average survival of southern pine beetle brood in untreated, cut-and-leave, and cut-and-top pines*

Treatment	Dec. 1975			Mar. 1976			July 1976			Aug. 1976			Sept. 1976			Average	
	Trees sampled	Brood survival	SD[1]	Trees sampled	Brood survival	SD	Trees sampled	Brood survival	SD	Trees sampled	Brood survival	SD	Trees sampled	Brood survival	SD	Brood survival	SD
	number	*percent*		*number*	*percent*		*number*	*percent*		*number*	*percent*		*number*	*percent*		*percent*	
Untreated	4	20	7	3	76	13	3	32	11	3	34	28	5	39	23	39	24
Cut-and-top	4	8	3	3	36	10	3	38	31	3	10	1	4	46	21	28	22
Cut-and-leave	4	13	10	0	18[2]		3	18	4	3	18	21	3	52	30	24	22
Average		14	8		49	25	....	29	19		21	21		44	23	30	23

[1] Standard Deviation.

[2] Data missing/not available: estimation done by regression analysis.

Table 2.—*Average number of offspring per attacking adult from recently attacked pines*

Treatment	Dec. 1975			15 June 1976			29 June 1976			Sept. 1976			Average	
	Trees sampled	Offspring[1]	SD[2]	Trees sampled	Offspring	SD	Trees sampled	Offspring	SD	Trees sampled	Offspring	SD	Brood survival	SD
		number			*number*			*number*			*number*		*number*	
Untreated	3	3.30	1.10a[3]	3	0.45	0.32	3	1.30	0.40	1	3.70		1.90	1.15a
Cut-and-top	1	1.20	b	3	.10	.04	3	.90	.07	2	.95	.35	.70	.15b
Cut-and-leave	3	1.60	1.10b	3	.04	.02	3	.90	.40	3	1.03	.49	.90	.80b
Average		2.30	1.10a		.20	.26b		1.00	.35b		1.45	1.1 b		

Per attacking adult.

Standard deviation.

[3] Means followed by the same letter in each column are not significantly different ($P < 0.05$).

There was no significant treatment-by-month interaction at the 0.05 level. This greater effect on early broods supports the findings of Ollieu (1969), but not those of Hodges and Thatcher (1976).

When compared to untreated pines, the number of offspring per attacking adult was significantly less for the cut-and-top and cut-and-leave treatments. Either lower egg production or higher brood mortality accounted for this difference. The number of December offspring per adult was significantly larger than those of the other three sampling dates.

CONCLUSIONS

In this evaluation, cut-and-leave and cut-and-top treatments significantly reduced SPB populations only in limited situations. When the felled trees were freshly attacked in the winter, populations were adversely affected. It appears that microenvironmental changes have a greater opportunity to affect the beetle in these trees. Population survival is reduced by different amounts, depending on treatment and date of application; however, it is impossible to eliminate the entire brood.

It is not known how much beetle population must be reduced to prevent the breakout of a controlled spot. In the summer, controlled spots may break out but few new ones are initiated, indicating that significant beetle mortality can probably be attributed to the dispersal phase. This assumption is based on the belief that when cut-and-leave and cut-and-top are applied, the broods are placed in a less than desirable environmental situation and produce adult beetles that are not physiologically capable of flying for very long distances and thus are not able to initiate new spots (Billings and Pase 1979).

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**Southern Forest
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New Orleans,
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Deer and Cattle Forage Selection on Louisiana Pine-Hardwood Sites

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SUMMARY

Seasonal diets of tame deer and cattle were studied on two clearcuts and two uneven-aged forest stands within the loblolly-shortleaf pine-hardwood forest type in central Louisiana. Seasonal diet composition data and relative selectivity ratings are presented for 264 plant taxa. Deer diets on forests and clearcuts were dominated yearlong by leafy browse. Cattle diets on forested sites consisted mainly of grasses during summer and fall and a mixture of grasses and browse during winter and spring. Cattle diets on clearcuts were dominated yearlong by grasses and grasslike plants.

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INTRODUCTION

The loblolly-shortleaf pine-hardwood forest type[1], occupying about 22 million hectares from east Texas to northeastern Virginia, ranks second only to bottomland hardwood forests as prime habitat for white-tailed deer (*Odocoileus virginianus*). Although stands are typically characterized by a dense understory of hardwoods, shrubs, and vines, substantial area is grazed by cattle. Knowledge of deer and cattle food habits within this forest type is needed to evaluate habitat quality, to assess deer-cattle competition, and to select and favor desirable forage species.

Literature on deer food habits within this pine-hardwood type is fairly extensive but not definitive. For example, herbaceous plants are now recognized as important dietary components, but much of the food habits literature is based on utilization surveys which emphasized woody plants (Goodrum and Reid 1959, Halls 1975). Furthermore, much of the literature deals only with relative use of different species without regard to forage availability (Lay 1967, Warren and Hurst 1981). Since forage preferences are a function of both use and availability, forage ratings based solely on relative use may not accurately depict preferences.

Very little is known regarding cattle food habits on pine-hardwood sites (McLeod 1953, Mitchell 1980, Thill and Martin 1980).

This report provides information on (1) seasonal diets of deer and cattle and (2) relative selectivity ratings for 264 plant taxa eaten on two clearcuts and two all-aged forest stands in central Louisiana. Data, based on direct observation of cattle and tame deer, were collected during each of the four seasons from June 1978 through July 1980. Findings for clearcuts and forest sites are presented separately.

METHODS

Study Areas

Food-habits data were obtained from four study areas on the Catahoula National Wildlife Management Preserve, Kisatchie National Forest, Grant Parish, Louisiana. Areas 1 and 5 supported uneven-aged, second-growth pine associated with an abundance of hardwoods, shrubs, and vines, but little herbaceous forage. Areas 3 and 4, clearcut 3 years prior to study initiation, produced abundant herbaceous and woody forages (Thill and Martin 1980). Areas 1 and 3 had a long history of moderate to heavy yearlong grazing by cattle and wild hogs, but light recent use. Herbage utilization estimates from March through September 1979 were 10% on Area 1 and 35% on Area 3, and were approximately the same during 1978 and 1980. Areas 4 and 5 had little or no cattle use for at least 10 years prior to this study. None of the areas had been burned for at least 5 years. The local deer population was healthy, heavily hunted, and below carrying capacity. Clearcut sampling areas averaged about 2.2 ha each; forest sites varied from 7 ha for Area 1 to 25 ha for Area 5.

Procedures

Basal area and density of trees 1.37 m or taller were measured using point-sampling procedures. Current-year production of browse ($\leqslant$1.52 m tall), forbs, grasses, and grasslike plants was estimated during September 1978 (1979 for Area 5). Frequency of occurrence data, provided as an index of relative availability, were obtained during June 1979 and July 1980 from an average of 194 circular 0.89 m^2 quadrats on each forest site and an average of 154 circular 0.22 m^2 quadrats on each clearcut. All measurements were collected at fixed intervals along randomly selected parallel transects. Woody plants

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[1] Scientific names of plants are listed in appendix 3.

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projecting over the plots to a height of 1.52 m and all herbaceous plants rooted within the plots were included in production measurements and tallied for frequency of occurrence determinations. Frequency data presented here are averages for 2 years.

Food-habits data were obtained by close observation of foraging cattle and tame deer. Feeding trials were conducted over a 31 to 53 day interval during each of the four seasons. Deer and cattle were generally observed for a minimum of 3 days on each area each season, with trial dates distributed fairly uniformly throughout each season. Data were usually collected from a minimum of 3 deer and 3 cattle, but as many as 9 animals of each type were observed. Feeding trials were begun at random starting points and lasted for 30 to 90 minutes, generally between 0800 and 1500 hours. Cattle were generally observed unrestrained; deer were leashed but were allowed to graze freely. Deer were grazed on a variety of sites prior to each trial and throughout taming and training to acquaint them with different associations of available forage. Between trials deer were maintained on a commercial horse and mule feed supplemented with a wide variety of native plants. Cattle grazed native forest range between trials and had yearlong access to salt and bone meal.

Diets were quantified using bite-count procedures (Thill and Martin 1980). Forest and clearcut data were treated separately. Diet composition values are percentages that each species contributed to the total bite-count for each season and area. Within each season and area, diet composition values of each species were averaged across years; these averages were then weighted across areas in proportion to the number of years of data available per area. Two years of deer and cattle data were collected on all sites for winter and spring. There were 2 years of deer and cattle fall data for Areas 1, 3, and 4, but only 1 year for Area 5. There were 2 years of summer cattle data for Areas 1, 3, and 4, and 1 year for Area 5. There were 3 years of deer summer data for Areas 1, 3, and 4, and 2 years for Area 5.

Forage selectivity values were computed by dividing the average percent diet composition value of each species by its average percent frequency of occurrence. Thus, given two plants represented equally in the diet, the one occurring most infrequently on the study area would receive the highest selectivity value. Plants which were eaten but not encountered during frequency of occurrence surveys were arbitarily assigned a frequency of one-half of the minimum—i.e., 0.05 for forests and 0.10 for clearcuts. Plants were then ranked on the basis of these selectivity values, divided into 5 groups, and assigned integer values of 1 (lowest selectivity) through 5 (highest selectivity); plants not eaten were assigned a value of zero.

Scientific names conform to the National List of Scientific Plant Names (U.S. Department of Agriculture 1982). Common names of trees are from Little

Table 1.—*Overstory characteristics of forested sampling areas and current-year production (ovendry weight in September) of understory plants on four study areas, Kisatchie National Forest, Louisiana*

	Forests		Clearcuts	
	Area 1	Area 5	Area 3	Area 4
Overstory[1]				
Stocking (stems/ha)				
Pine	612	383		
Hardwood	377	961		
Total	989	1,344		
Basal Area (m²/ha)				
Pine	18.7	18.6		
Hardwood	4.0	8.5		
Total	22.7	27.1		
Understory Production (kg/ha below 1.52 m)				
Woody plants	301	233	876	750
Grasses	69	92	1,358	1,308
Grasslike plants	2	8	254	600
Forbs	32	21	839	222
Total	404	354	3,327	2,880

[1] Overstory measurements include trees ⩾ 1.37 m in height.

(1979); those for other plants follow either Kelsey and Dayton (1942), Wolff (1954), Grelen and Duvall (1966), Gould (1969), or Scott and Wasser (1980). A cross-reference of scientific and common names, including synonymous scientific names, appears in appendix 3.

RESULTS

Overstory/Understory Conditions

Total stocking of pine and hardwood trees measuring 1.37 m or taller averaged 1166 stems/ha on Areas 1 and 5 (table 1). Stocking of pines was higher on Area 5, but basal area was comparable for both forests. Hardwood stocking and basal area on Area 5 were more than twice that of Area 1.

Browse production, consisting of current-year leaf and twig growth from hardwoods, shrubs, and vines, averaged 267 kg/ha on forest sites and 813 kg/ha on clearcuts (table 1). Total herbage production averaged 112 kg/ha on forest sites and 2,290 kg/ha on clearcuts.

Diets and Forage Preferences

Diet composition summaries are based on total deer and cattle bite-counts of 123,923 and 246,270, respectively. Deer were observed for a total of 344 hours, cattle for 205. Total bite-counts per area within seasons varied from 1,301 to 7,676 for deer and from 2,406 to 14,878 for cattle (table 2). Inclusive sampling dates of feeding trials, the average number of trials per season, and the average number of animals observed per trial varied among seasons and years (table 2).

Deer diets on forests were dominated yearlong by woody plants. During late spring, summer, fall, and early winter, deer browse consisted primarily of green leaves of both deciduous and evergreen woody plants. Leaves and some succulent woody twig ends were eaten during early spring, and a few hardened twigs were consumed with evergreen foliage during winter. Grasses dominated cattle summer and fall diets on forests, whereas woody plants and grasses contributed nearly equally to cattle winter and spring diets (fig. 1). Deer diets on clearcuts were dominated by woody plants yearlong, but cattle diets consisted mainly of grasses and grasslike plants (fig. 2). On an annual basis, forbs contributed an average of 9.0 and 2.0% to deer and cattle diets on forests, respectively (appendix 1), compared with 11.1 and 6.0% on clearcuts (appendix 2). Deer and rabbit (*Sylvilagus* spp.) fecal pellets made up as much as 0.4% of deer diets on clearcuts and 0.1% on forests. Fungi were not eaten by cattle on clearcuts, but furnished as much as 0.2% of their diet on forests. Fungi were eaten by deer on clearcuts and forests and comprised as much as 2.4% of their diet (appendices 1 and 2).

Tabe 2.—*Inclusive sampling dates of feeding trials, average number of trials per season, average number of animals observed per trial, and number of bites recorded for tame deer (D) and cattle (C). Means are for all study areas*

Season	Sampling dates	Animal	Average number trials	Average number animals observed	Bite-Counts	
					$\bar{x}$	Range
Summer	6/20–8/10/78	D	4.3	2.1	4,488	3,985– 4,751
		C	2.3	3.0	8,340	5,781–11,554
	7/2–8/23/79	D	4.0	4.0	6,162	5,293– 6,988
		C	3.0	4.0	10,751	9,009–12,806
	7/1–7/23/80[1]	D	3.0	3.0	1,747	1,301– 2,656
Fall	10/10–11/15/78	D	3.0	3.9	2,805	2,782– 2,844
		C	2.7	3.8	5,707	4,042– 7,172
	10/10–11/28/79	D	4.0	3.0	3,533	3,208– 3,760
		C	3.0	4.9	7,687	5,491–10,226
Winter	1/17–3/1/79	D	2.8	4.7	2,011	1,509– 2,511
		C	2.2	3.8	3,897	2,406– 5,497
	1/8–2/29/80	D	4.0	3.0	2,626	2,115– 2,903
		C	3.2	4.8	5,723	4,540– 7,150
Spring	4/3–5/10/79	D	3.0	4.6	6,042	5,270– 7,676
		C	3.0	3.8	9,482	10,676–14,878
	3/31–5/14/80	D	4.0	3.0	3,388	2,978– 3,644
		C	3.0	5.0	9,316	7,704–14,521

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[1] Cattle diets were not evaluated during the summer of 1980.

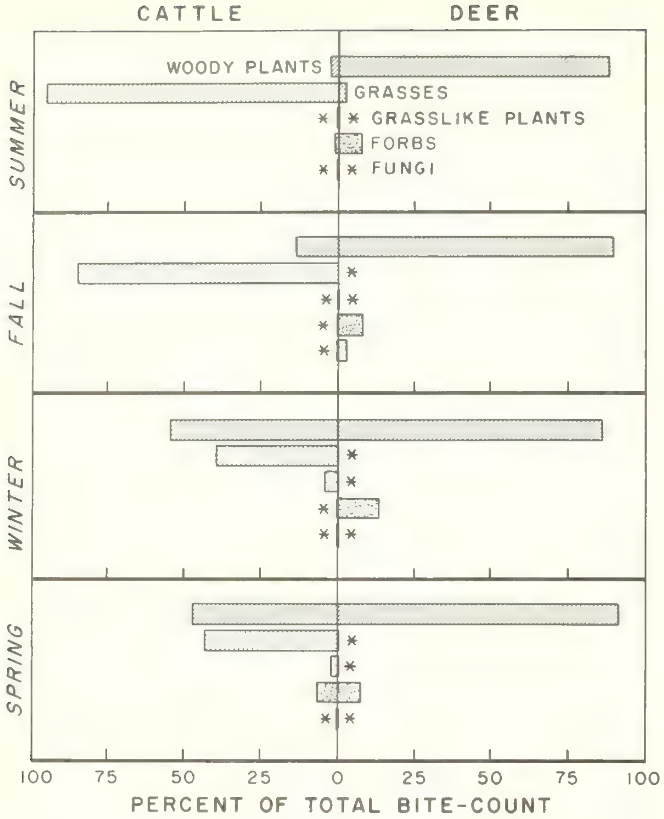

Figure 1.—*Percent contribution of woody plants, grasses, grasslike plants, forbs (plus ferns and fecal pellets), and fungi to deer and cattle diets on forested pine-hardwood sites in central Louisiana. Asterisks denote less than 1%.*

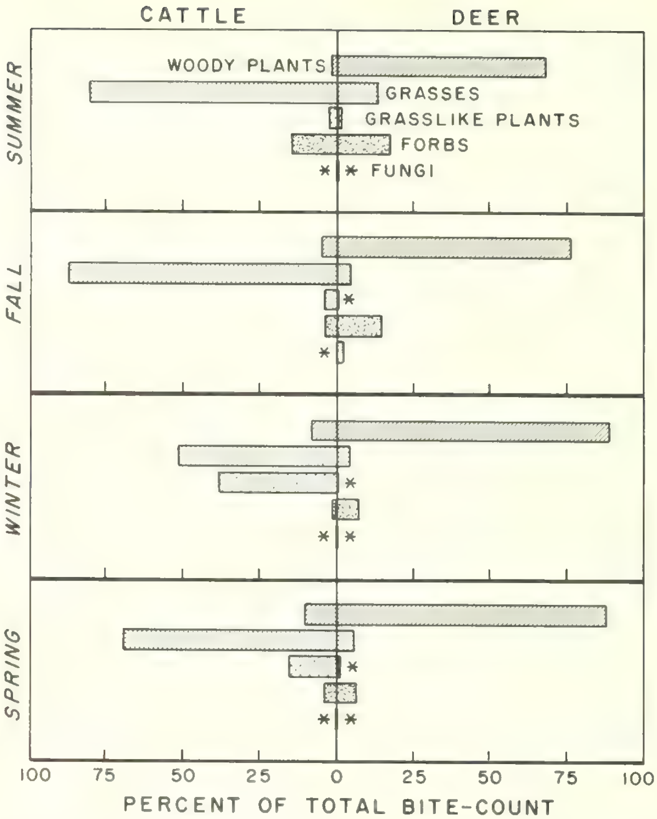

Figure 2.—*Percent contribution of woody plants, grasses, grasslike plants, forbs (plus ferns and fecal pellets), and fungi to deer and cattle diets on recently clearcut pine-hardwood sites in central Louisiana. Asterisks denote less than 1%.*

Data on mast production were not obtained, but observations indicated that most of the available mast was produced by American beautyberry and several species of blackberry. Consequently, with the exception of these species, selectivity ratings for woody plants refer primarily to browse. Deer fall selectivity ratings for American beautyberry are mainly for fruit, as deer seldom consumed leaves or twigs of this species. Cattle were less selective and typically consumed the entire fruit mass together with adjacent stem and leaves. Cattle seldom ate blackberry fruit, but deer readily ate blackberries from about mid-May through late June. Thus, deer selectivity ratings for blackberries during spring and summer reflect combined use of browse and fruit.

Seasonal use and relative selectivity values are presented for a total of 264 plant taxa (appendices 1 and 2). Of these, 204 plants (82 woody, 24 grasses, 10 grasslike, 85 forbs, and 3 ferns) were eaten by deer and/or cattle on forests sites and 233 plants (74 woody, 35 grasses, 15 grasslike, 107 forbs, and 2 ferns) were eaten on clearcuts. Of the 264 plants for which selectivity data are presented, 31 were eaten only on forest sites, 60 only on clearcuts, and 173 were eaten under both situations.

DISCUSSION

An animal's preference for a particular forage component is a reflection of the likelihood of that component being chosen if offered equally with other foods (Johnson 1980). Preference determinations are possible in cafeteria-type trials, but not under field conditions as described here. Use is said to be selective if forage components are used disproportionally to their availability (Johnson 1980).

The distinction between preference and selectivity is important but not always understood or applied. That certain presumably unpalatable plants received high selectivity ratings seasonally was probably due to a scarcity of more desirable forages rather than bias associated with tame deer. This was exemplified during winter when waxmyrtle, dwarf palmetto, and pines received relatively high forage ratings for deer on forests. Palatable green forage was scarce during winter on both forests. Consequently, deer resorted to using green foliage from these less palatable plants rather than dead or dormant foliage from more desirable species.

Frequency of occurrence data collected during summer were used to compute forage ratings throughout the year. Forage availability data for each season would have been preferred, but summer data should be adequate for most plants occurring on these sites. Possible exceptions would include ephemeral species such as violet woodsorrel, common oxalis, Nuttall wildindigo, and some of the violets. Selectivity ratings for these species may be over-rated. Furthermore, all ratings presented here are site-specific, and users should consult a variety of sources before drawing conclusions for other sites.

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Appendix 1

Seasonal composition of cattle and tame deer diets, percent frequency of occurrence of forages, and relative forage selectivity ratings on two forested pine-hardwood sites in central Louisiana.[1]

Species[2]	% Freq.[3]	Deer								Cattle							
		% Diet composition				Selectivity[5]				% Diet composition				Selectivity			
		SU	FA	WI	SP[4]	SU	FA	WI	SP	SU	FA	WI	SP	SU	FA	WI	SP
Woody Plants																	
Acer rubrum	37.8	0.6	2.0	0.7	1.9	2	2	2	3	0.2	1.1	0.2	1.2	2	4	2	2
Aesculus parviflora	0.0	0.0	0.0	tr[6]	tr	0	0	4	4	0.0	0.0	0.0	0.0	0	0	0	0
Ampelopsis arborea	0.0	tr	0.0	0.0	tr	3	0	0	3	0.0	0.0	0.0	0.0	0	0	0	0
Aralia spinosa	0.0	0.0	0.0	0.0	tr	0	0	0	3	0.0	0.0	0.0	0.0	0	0	0	0
Ascyrum hypericoides	2.6	tr	0.1	0.1	tr	1	2	2	1	0.0	0.0	tr	0.0	0	0	2	0
A. stans	1.5	0.2	0.1	0.3	tr	4	2	4	1	0.0	tr	tr	0.0	0	1	3	0
Baccharis halimifolia	0.0	0.0	0.0	0.0	tr	0	0	0	5	0.0	0.0	0.0	0.1	0	0	0	5
Berchemia scandens	7.2	13.4	9.1	0.1	3.1	5	5	2	5	tr	tr	0.0	0.3	1	1	0	3
Bignonia capreolata	6.1	0.1	0.1	0.8	0.1	1	1	4	1	0.0	0.0	tr	tr	0	0	1	1
Callicarpa americana	18.7	0.2	4.5	0.4	tr	1	4	2	1	tr	4.1	tr	0.2	1	5	1	1
Campsis radicans	0.4	0.4	0.2	0.0	0.1	5	5	0	4	tr	0.0	0.0	0.0	4	0	0	0
Carpinus caroliniana	0.1	0.1	0.4	0.1	0.2	5	5	5	5	0.0	0.0	0.1	0.1	0	0	5	5
Carya spp.	[7]	0.0	0.0	tr	0.0					0.0	0.0	0.0	tr				
C. cordiformis	0.0	tr	tr	0.0	0.0	3	4	0	0	tr	0.0	0.1	0.0	4	0	5	0
C. tomentosa	1.2	tr	0.1	0.0	0.1	1	2	0	3	0.0	0.0	0.0	tr	0	0	0	2
Chionanthus virginicus	4.1	0.5	0.1	tr	1.5	4	1	1	5	tr	0.1	0.0	0.5	2	3	0	3
Cornus florida	4.7	1.6	0.7	0.9	1.6	5	3	4	5	0.1	0.2	0.2	4.3	4	4	3	5
Crataegus crus-galli	4.5	1.7	1.2	0.1	2.8	5	4	2	5	tr	0.1	0.0	0.2	2	3	0	2
C. marshallii	14.8	1.6	1.8	0.2	3.5	4	3	1	4	tr	0.1	0.0	0.2	2	2	0	2
C. spathulata	1.1	0.1	0.2	0.1	0.4	3	4	3	5	0.0	0.0	tr	tr	0	0	2	1
Diospyros virginiana	7.5	0.5	1.9	0.1	0.2	3	4	2	2	tr	0.1	0.0	tr	1	2	0	1
Fagus grandifolia	0.7	0.1	0.1	tr	0.2	4	3	2	4	tr	0.0	0.1	0.2	4	0	4	5
Fraxinus pennsylvanica	1.4	0.1	0.2	0.5	0.1	3	4	4	3	0.1	tr	0.0	0.2	4	3	0	4
Gelsemium sempervirens	55.9	6.9	16.6	35.5	2.4	4	4	5	2	tr	1.0	29.8	0.3	1	3	5	1
Halesia diptera •	0.0	0.0	0.0	0.0	0.1	0	0	0	5	0.0	0.0	0.0	0.0	0	0	0	0
Hamamelis virginiana	0.3	tr	0.0	0.0	0.2	4	0	0	5	0.0	0.0	0.0	0.0	0	0	0	0
Ilex decidua	9.8	8.7	11.4	0.1	9.1	5	5	1	5	tr	0.1	tr	0.3	1	3	1	2
I. opaca	1.4	tr	0.0	0.2	0.5	2	0	3	4	0.0	0.0	0.2	0.0	0	0	4	0
I. vomitoria	0.2	tr	0.3	0.9	0.0	3	5	5	0	0.0	0.0	tr	0.0	0	0	3	0
Liquidambar styraciflua	17.6	1.7	1.3	2.4	1.7	4	2	4	3	tr	0.5	0.1	5.8	1	4	2	4
Lonicera japonica	0.0	0.2	0.8	0.8	0.1	5	5	5	5	0.0	0.0	0.0	0.0	0	0	0	0
L. sempervirens	0.3	tr	0.0	0.0	tr	3	0	0	4	0.0	0.0	0.0	0.0	0	0	0	0
Magnolia grandiflora	0.0	0.0	0.0	0.4	0.0	0	0	5	0	0.0	0.0	tr	0.0	0	0	5	0
M. virginiana	0.1	0.0	tr	tr	tr	0	3	3	4	0.0	0.0	0.0	0.0	0	0	0	0
Manfreda virginica	0.0	0.0	0.0	0.0	tr	0	0	0	3	tr	0.0	0.0	0.0	5	0	0	0
Morus rubra	0.2	tr	0.2	0.0	0.0	5	5	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Myrica cerifera	10.4	tr	0.4	8.0	0.1	1	2	5	2	0.0	0.0	10.1	tr	0	0	5	1
Nyssa sylvatica	10.0	10.3	2.0	0.8	9.7	5	4	3	5	0.2	0.1	tr	2.8	4	3	1	4
Ostrya virginiana	0.1	0.0	0.0	0.0	tr	0	0	0	3	0.0	tr	0.2	0.0	0	4	5	0
Parthenocissus quinquefolia	2.0	0.1	0.0	0.0	0.8	2	0	0	5	0.0	0.0	0.0	0.5	0	0	0	4
Pinus echinata	0.0	tr	tr	tr	0.0	3	4	5	0	0.0	0.0	0.0	0.0	0	0	0	0
P. palustris	0.0	0.0	0.0	tr	0.0	0	0	5	0	0.0	0.0	0.1	0.0	0	0	5	0
P. taeda	23.4	0.2	0.1	1.1	0.1	1	1	3	1	tr	0.2	0.7	0.0	1	2	2	0

Species[2]	% Freq.[3]	Deer								Cattle							
		% Diet composition				Selectivity[5]				% Diet composition				Selectivity			
		SU	FA	WI	SP[4]	SU	FA	WI	SP	SU	FA	WI	SP	SU	FA	WI	SP
Prunus mexicana	2.2	0.2	0.3	tr	0.3	3	3	1	3	tr	tr	0.0	tr	2	3	0	2
P. serotina	4.2	0.3	0.4	0.6	1.2	3	3	4	4	tr	0.3	0.1	1.6	3	4	3	5
P. umbellata	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	3
Quercus alba	1.7	0.3	0.4	0.1	0.6	4	4	3	5	tr	0.2	0.0	0.9	3	5	0	5
Q. falcata	7.9	0.2	3.0	0.5	0.8	2	5	3	3	0.1	1.0	1.5	0.9	2	5	4	3
Q. falcata var. *pagodifolia*	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	0.1	0	0	0	5
Q. laurifolia	0.3	0.0	0.0	0.0	tr	0	0	0	4	tr	0.0	0.0	tr	4	0	0	4
Q. marilandica	6.1	0.0	0.0	0.1	0.3	0	0	2	2	0.0	tr	0.1	1.1	0	1	2	4
Q. nigra	5.1	0.2	0.6	4.0	0.8	3	3	5	4	tr	0.1	1.8	1.5	3	4	4	4
Q. phellos	0.4	0.0	0.0	0.0	0.1	0	0	0	4	0.0	0.0	0.0	0.2	0	0	0	5
Q. stellata	12.8	1.0	0.5	1.5	2.5	3	2	3	4	0.2	0.3	1.1	2.7	3	4	3	4
Q. velutina	7.2	0.1	0.3	tr	1.1	1	2	1	4	tr	0.1	0.2	1.5	2	2	3	4
Rhamnus caroliniana	0.0	0.0	0.1	0.0	0.0	0	5	0	0	0.0	0.0	tr	0.0	0	0	3	0
Rhododendron nudiflorum	0.1	0.1	tr	0.1	0.2	5	4	5	5	0.0	0.0	0.0	0.0	0	0	0	0
Rhus copallina	4.5	tr	0.0	0.2	0.2	1	0	2	3	0.0	tr	0.0	0.1	0	1	0	2
Rubus spp.	36.7	2.2	2.0	2.7	3.1	3	2	3	3	tr	0.3	0.2	2.8	1	2	2	3
Sabal minor	0.1	0.0	0.0	0.1	0.0	0	0	5	0	0.0	0.0	0.1	0.0	0	0	4	0
Sambucus canadensis	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	0.2	0	0	0	5
Sassafras albidum	3.3	3.9	2.1	0.2	3.9	5	5	3	5	tr	tr	tr	1.2	1	2	1	5
Smilax bona-nox	15.9	2.3	2.6	1.6	2.8	4	3	3	4	0.2	0.2	0.3	1.2	3	2	2	3
S. glauca	19.9	4.4	2.7	7.2	2.3	5	3	4	3	tr	0.2	2.0	0.2	1	2	3	1
S. hispida	0.0	0.0	tr	0.0	tr	0	5	0	5	tr	0.0	0.0	tr	5	0	0	3
S. pumila	0.1	0.0	0.0	tr	0.0	0	0	4	0	0.0	0.0	0.0	0.0	0	0	0	0
S. rotundifolia	6.3	1.4	0.9	0.2	2.1	5	3	2	5	0.1	0.1	tr	1.6	3	3	1	4
S. smallii	1.0	0.1	1.5	4.0	0.3	4	5	5	5	0.0	tr	1.5	0.0	0	2	5	0
Styrax grandifolia	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	0.1	0	0	0	5
Symplocos tinctoria	0.2	0.5	0.5	5.5	0.5	5	5	5	5	0.0	0.0	3.1	0.1	0	0	5	5
Toxicodendron radicans	8.9	0.9	0.2	0.0	2.1	4	1	0	4	tr	0.0	0.0	1.9	2	0	0	4
T. toxicarium	2.7	0.3	tr	0.0	0.1	4	1	0	2	0.0	0.0	0.0	0.4	0	0	0	4
Trachelosperum difforme	8.1	1.0	0.5	0.0	tr	4	2	0	1	tr	tr	0.0	0.0	1	1	0	0
Ulmus alata	4.6	10.6	4.9	0.1	9.3	5	5	2	5	tr	0.3	0.0	0.7	2	4	0	3
Vaccinium arboreum	16.7	0.7	0.6	1.0	2.7	3	2	3	4	0.1	tr	0.3	0.4	2	1	2	2
V. caesium	0.5	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	1
V. corymbosum and *V. stamineum*	18.4	1.0	1.9	1.3	1.9	3	3	3	3	0.1	0.1	1.0	3.9	2	2	3	4
V. elliottii	5.9	0.3	0.1	0.1	0.5	3	1	2	3	tr	0.0	0.2	1.2	1	0	3	4
Viburnum dentatum	15.0	5.0	5.5	0.1	4.0	5	5	1	4	0.6	2.4	tr	1.8	4	5	1	3
V. rufidulum	0.3	tr	tr	0.0	0.1	3	3	0	5	tr	0.0	0.0	0.1	3	0	0	4
Vitis aestivalis	1.5	0.5	0.3	0.0	0.4	5	4	0	4	0.0	0.0	0.0	0.1	0	0	0	3
V. rotundifolia	23.9	2.2	2.1	0.2	6.7	4	3	1	4	0.1	0.4	tr	2.1	2	3	1	3
Yucca spp.	0.5	0.0	0.0	0.0	0.0	0	0	0	0	0.0	tr	0.1	0.0	0	3	4	0
Unknown woody plants		tr	0.0	0.0	0.0					0.0	0.0	0.0	0.0				
Subtotals		88.9	89.7	86.0	91.4					2.5	13.7	55.5	47.7				

Species[2]	% Freq.[3]	Deer								Cattle							
		% Diet composition				Selectivity[5]				% Diet composition				Selectivity			
		SU	FA	WI	SP[4]	SU	FA	WI	SP	SU	FA	WI	SP	SU	FA	WI	SP
Grasses																	
Andropogon elliottii	0.1	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.1	0.6	0.0	0	5	5	0
A. gerardii	0.1	tr	0.0	0.0	0.0	4	0	0	0	3.5	0.6	0.1	0.0	5	5	5	0
A. subtenuis	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	tr	0.0	0	0	4	0
A. virginicus	2.9	0.2	0.0	0.0	0.0	3	0	0	0	0.4	3.4	0.4	0.1	5	5	4	2
Aristida purpurascens	0.1	0.0	0.0	0.0	0.0	0	0	0	0	0.0	tr	0.0	tr	0	4	0	2
Arundinaria gigantea	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	5
Axonopus affinis	0.2	tr	0.0	0.0	0.0	2	0	0	0	3.2	0.0	0.3	tr	5	0	5	3
Chasmanthium laxum and *C. sessiliflorum*	66.6	2.2	tr	tr	0.3	2	1	1	1	49.8	57.3	26.1	31.9	5	5	4	5
Dichanthelium spp.[8]	23.8	0.2	0.0	0.1	0.1	1	0	1	1	0.3	tr	tr	3.4	3	1	1	3
Eragrostis spectabilis	1.7	0.0	0.0	0.0	0.0	0	0	0	0	0.1	tr	tr	0.0	4	3	2	0
Erianthus contortus	0.0	tr	0.0	0.0	0.0	4	0	0	0	0.1	0.3	0.0	0.0	5	5	0	0
Gymnopogon ambiguus and *G. brevifolius*	0.1	tr	0.0	0.0	0.0	4	0	0	0	0.0	tr	0.0	0.0	0	5	0	0
Melica mutica	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	5
Muhlenbergia expansa	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	tr	0.3	0.0	0	5	5	0
Panicum anceps var. *rhizomatum*	3.5	0.0	0.0	0.0	tr	0	0	0	1	22.1	1.4	0.9	0.7	5	5	4	4
P. virgatum	0.1	tr	0.0	0.0	0.0	5	0	0	0	tr	tr	0.0	0.4	5	5	0	5
Paspalum floridanum	1.7	tr	0.0	0.0	0.0	2	0	0	0	0.3	0.2	tr	0.0	5	5	2	0
P. laeve var. *circulare*	0.3	0.0	0.0	0.0	0.0	0	0	0	0	tr	0.0	0.0	0.0	4	0	0	0
P. plicatulum	1.0	0.0	0.0	0.0	tr	0	0	0	2	0.8	tr	0.0	0.0	5	2	0	0
P. urvillei	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.7	0.0	0.0	tr	5	0	0	3
Schizachyrium scoparium var. *divergens*	26.5	0.1	0.0	tr	0.2	1	0	1	1	14.6	22.3	11.4	7.0	5	5	4	4
Sorghastrum nutans	0.0	0.0	0.0	0.0	0.0	0	0	0	0	tr	0.0	0.0	0.0	5	0	0	0
Stipa avenacea	0.0	0.0	0.0	0.0	0.0	0	0	0	0	tr	0.0	0.0	0.0	5	0	0	0
Tridens flavus	0.1	0.0	0.0	0.0	0.0	0	0	0	0	0.1	0.0	0.0	tr	5	0	0	2
Subtotals		2.7	tr	0.1	0.6					96.1	85.7	40.1	43.6				
Grasslike Plants																	
Carex complanata	7.0	tr	0.0	0.0	0.0	1	0	0	0	tr	tr	0.1	0.1	1	1	2	2
C. flaccosperma	1.1	0.0	tr	0.0	0.0	0	2	0	0	tr	0.0	0.0	0.3	2	0	0	4
C. vulpinoidea	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	3
Juncus effusus	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	5
J. tenuis	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	4
J. validus	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	0.1	0	0	0	5
Rhynchospora globularis and *R. glomerata*	4.4	0.0	0.0	0.0	tr	0	0	0	1	0.0	0.0	0.3	0.1	0	0	3	1
R. inexpansa	7.0	0.0	0.0	0.0	0.0	0	0	0	0	tr	tr	0.4	0.4	2	1	3	3
Scirpus cyperinus	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	3
Scleria oligantha	16.1	0.1	tr	0.1	tr	1	1	1	1	0.2	0.2	3.5	1.1	3	3	4	3
Subtotals		0.1	0.1	0.1	0.1					0.2	0.2	4.3	2.1				

Species[2]	% Freq.[3]	Deer								Cattle							
		% Diet composition				Selectivity[5]				% Diet composition				Selectivity			
		SU	FA	WI	SP[4]	SU	FA	WI	SP	SU	FA	WI	SP	SU	FA	WI	SP
Forbs and Ferns																	
Ageratina altissima	0.0	tr	tr	0.0	tr	5	4	0	5	0.0	0.0	0.0	0.0	0	0	0	0
Aletris farinosa	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	5
Antennaria plantaginifolia	0.1	tr	0.0	tr	0.1	2	0	3	5	0.0	0.0	0.0	tr	0	0	0	4
Apocynum cannabinum	0.3	tr	0.0	0.0	0.0	2	0	0	0	0.0	0.0	0.0	tr	0	0	0	1
Aristolochia serpentaria	0.7	tr	0.0	0.0	tr	2	0	0	1	0.0	0.0	0.0	0.0	0	0	0	0
Aster dumosus	6.7	0.1	0.3	tr	tr	1	2	1	1	0.0	tr	tr	0.1	0	1	1	1
A. patens	3.3	0.1	0.3	0.1	0.2	2	3	2	2	0.0	tr	0.0	0.1	0	2	0	2
Boltonia diffusa	0.5	tr	tr	0.0	0.0	2	2	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Cassia fasciculata	1.2	tr	tr	0.0	0.0	1	1	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Centrosema virginianum	0.0	0.0	0.0	0.0	tr	0	0	0	4	0.0	0.0	0.0	0.0	0	0	0	0
Conoclinium coelestinum	0.0	tr	tr	0.0	0.0	5	4	0	0	0.0	0.0	0.0	tr	0	0	0	4
Coreopsis lanceolata	0.0	0.0	0.0	0.0	tr	0	0	0	5	0.0	0.0	0.0	tr	0	0	0	3
Desmodium spp.	2.9	0.4	0.4	0.0	0.1	4	3	0	2	tr	0.0	0.0	tr	3	0	0	1
D. ciliare	0.0	0.0	0.0	0.0	tr	0	0	0	3	0.0	0.0	0.0	0.0	0	0	0	0
D. dillenii	0.9	tr	tr	0.0	tr	2	2	0	2	0.0	0.0	0.0	tr	0	0	0	1
D. paniculatum	0.4	tr	tr	0.0	0.0	2	2	0	0	tr	0.0	0.0	tr	4	0	0	2
D. rigidum	0.4	tr	tr	0.0	0.0	1	1	0	0	tr	0.0	0.0	0.0	2	0	0	0
D. rotundifolium	0.1	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	2
Duchesnea indica	0.0	0.0	0.0	0.0	0.4	0	0	0	5	0.0	0.0	0.0	0.0	0	0	0	0
Elephantopus tomentosus	2.1	tr	0.0	0.0	tr	2	0	0	1	tr	0.0	0.0	0.0	3	0	0	0
Erigeron strigosus	0.0	tr	0.0	0.0	0.0	3	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Eryngium yuccifolium	0.6	tr	0.0	0.0	tr	3	0	0	1	0.1	tr	0.0	0.2	5	4	0	4
Eupatorium spp.		0.0	0.0	0.0	0.0					tr	0.0	0.0	0.0				
E. album	0.1	0.1	tr	0.0	0.0	5	4	0	0	0.0	0.0	0.0	0.0	0	0	0	0
E. capillifolium	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	5
E. rotundifolium	4.3	tr	0.0	0.0	tr	1	0	0	1	0.0	tr	0.0	tr	0	1	0	1
E. semiserratum	0.5	tr	0.0	0.0	0.0	2	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Euphorbia corollata	9.1	0.2	0.0	0.0	0.2	2	0	0	2	tr	0.0	0.0	0.1	1	0	0	1
Euthamia leptocephala	0.4	0.0	0.1	0.0	tr	0	4	0	2	0.0	0.0	0.0	0.0	0	0	0	0
Galactia volubilis	5.3	0.5	0.1	0.0	0.0	4	1	0	0	0.1	0.0	0.0	0.0	3	0	0	0
Galium pilosum	0.4	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	1
Helenium flexuosum	2.0	tr	0.0	tr	tr	1	0	1	1	0.0	0.0	0.0	tr	0	0	0	1
Helianthus angustifolius	3.0	0.0	0.0	0.0	0.1	0	0	0	2	0.2	0.0	0.0	0.1	4	0	0	2
H. hirsutus	1.0	tr	0.0	0.0	0.0	2	0	0	0	0.0	0.0	0.0	0.1	0	0	0	3
Heterotheca graminifolia	1.3	0.0	0.0	0.0	tr	0	0	0	2	tr	0.0	0.0	tr	3	0	0	2
H. pilosa	0.5	0.0	0.0	0.0	0.0	0	0	0	0	0.0	tr	0.0	0.0	0	4	0	0
Hieracium gronovii	2.8	tr	0.0	0.0	0.1	2	0	0	2	0.0	tr	0.0	tr	0	1	0	1
Hypericum drummondii	0.0	0.0	0.0	tr	0.0	0	0	4	0	0.0	0.0	0.0	0.0	0	0	0	0
Krigia dandelion	0.0	0.0	0.0	0.0	tr	0	0	0	4	0.0	0.0	0.0	0.0	0	0	0	0
Lactuca spp.	0.1	0.1	0.0	0.0	0.0	5	0	0	0	0.0	0.0	0.0	tr	0	0	0	2
Lespedeza hirta	0.0	tr	0.0	0.0	0.0	5	0	0	0	tr	0.0	0.0	0.0	4	0	0	0
L. procumbens and *L. repens*	4.8	0.1	tr	0.0	0.1	2	1	0	2	0.2	0.0	0.0	0.1	4	0	0	2

Species[2]	% Freq.[3]	Deer								Cattle							
		% Diet composition				Selectivity[5]				% Diet composition				Selectivity			
		SU	FA	WI	SP[4]	SU	FA	WI	SP	SU	FA	WI	SP	SU	FA	WI	SP
L. striata	0.0	tr	0.0	0.0	0.0	4	0	0	0	0.0	0.0	0.0	tr	0	0	0	5
L. violacea	0.5	0.1	0.0	0.0	0.0	4	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0
L. virginica	1.1	0.2	tr	0.0	0.1	4	1	0	3	tr	0.0	0.0	tr	3	0	0	1
Liatris spp.	7.6	0.1	tr	0.0	0.4	1	1	0	3	0.2	0.0	0.0	3.9	3	0	0	5
L. cylindracea	0.0	0.0	tr	0.0	0.0	0	4	0	0	0.0	0.0	0.0	0.0	0	0	0	0
L. pycnostachya	0.2	0.0	0.0	0.0	tr	0	0	0	4	0.0	tr	0.0	0.0	0	4	0	0
Linum virginianum	0.1	0.0	0.0	0.0	0.0	0	0	0	0	tr	0.0	0.0	0.0	4	0	0	0
Lobelia appendiculata	0.1	0.0	0.0	0.0	tr	0	0	0	3	tr	0.0	0.0	0.0	3	0	0	0
L. puberula	1.0	0.1	tr	0.0	tr	4	1	0	2	0.0	0.0	0.0	0.0	0	0	0	0
Ludwigia alternifolia	0.0	0.0	0.0	0.0	tr	0	0	0	4	0.0	0.0	0.0	tr	0	0	0	3
L. glandulosa	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	4
Mecardonia acuminata	0.0	tr	0.0	tr	0.0	5	0	4	0	0.0	0.0	0.0	0.0	0	0	0	0
Mitchella repens	26.4	4.2	5.4	12.0	2.5	4	4	5	3	0.0	0.0	0.1	0.0	0	0	1	0
Oxalis stricta	6.0	tr	0.0	0.0	0.1	1	0	0	2	0.0	0.0	0.0	tr	0	0	0	1
O. violacea	2.7	0.0	0.0	0.0	2.4	0	0	0	5	0.0	0.0	0.0	0.2	0	0	0	3
Passiflora lutea	0.1	0.0	tr	0.0	tr	0	3	0	3	0.0	0.0	0.0	0.0	0	0	0	0
Penstemon australis	0.0	0.0	0.0	0.0	tr	0	0	0	3	0.0	0.0	tr	0.0	0	0	4	0
Plantago virginica	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	0.1	0	0	0	5
Polygala polygama	0.0	0.0	tr	0.0	tr	0	5	0	2	0.0	0.0	0.0	0.0	0	0	0	0
Polypodium polypodioides	0.1	tr	0.0	0.1	tr	5	0	5	5	0.0	0.0	0.0	0.0	0	0	0	0
Prunella vulgaris	0.4	tr	0.0	0.0	tr	3	0	0	3	0.0	0.0	0.0	tr	0	0	0	2
Pteridium aquilinum var. *pseudocaudatum*	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	4
Pycnanthemum albescens	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	5
P. tenuifolium	0.8	tr	0.0	0.0	0.0	1	0	0	0	0.0	0.0	0.0	0.1	0	0	0	3
Rhexia mariana	2.3	0.1	0.1	0.0	tr	3	1	0	1	0.1	0.0	tr	tr	4	0	2	1
Rudbeckia grandiflora	1.4	tr	0.0	0.0	0.3	2	0	0	4	tr	0.0	0.0	1.0	3	0	0	5
R. hirta	0.4	tr	0.0	0.0	0.0	1	0	0	0	0.0	0.0	0.0	tr	0	0	0	3
Ruellia pedunculata	8.5	0.4	0.3	0.0	0.1	3	2	0	1	tr	tr	0.0	tr	1	1	0	1
Salvia azurea var. *grandiflora*	1.2	0.0	0.0	0.0	0.0	0	0	0	0	tr	0.0	0.0	tr	2	0	0	2
S. lyrata	0.2	0.0	0.0	0.0	tr	0	0	0	2	0.0	0.0	0.0	tr	0	0	0	4
Sanicula canadensis	0.3	0.0	0.0	0.0	tr	0	0	0	2	0.0	0.0	0.0	0.0	0	0	0	0
Schrankia uncinata	1.4	0.0	0.0	0.0	tr	0	0	0	1	tr	0.0	0.0	tr	1	0	0	1
Scutellaria elliptica	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	3
S. integrifolia	3.4	0.0	0.0	0.0	tr	0	0	0	1	0.0	0.0	0.0	tr	0	0	0	1
Selaginella spp.	2.4	tr	0.2	1.0	0.1	1	3	5	2	0.0	0.0	0.0	0.0	0	0	0	0
Seymeria cassioides	0.1	0.0	0.1	0.0	0.0	0	5	0	0	0.0	tr	0.0	0.0	0	4	0	0
Solidago spp.	0.7	0.0	0.0	0.0	tr	0	0	0	2	0.0	0.0	0.0	tr	0	0	0	2
S. altissima	0.0	0.0	0.0	0.0	tr	0	0	0	4	0.0	0.0	0.0	0.1	0	0	0	5
S. nitida	0.1	0.0	0.0	0.0	tr	0	0	0	2	0.0	0.0	0.0	0.0	0	0	0	0
S. odora	1.2	tr	tr	tr	tr	1	1	2	1	0.0	tr	tr	0.0	0	2	1	0
S. rugosa	2.1	tr	0.2	tr	0.0	1	3	1	0	0.0	tr	0.0	tr	0	3	0	2
Stylisma humistrata	0.0	0.4	0.0	0.0	0.0	5	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0

Species[2]	% Freq.[3]	Deer								Cattle							
		% Diet composition				Selectivity[5]				% Diet composition				Selectivity			
		SU	FA	WI	SP[4]	SU	FA	WI	SP	SU	FA	WI	SP	SU	FA	WI	SP
Stylosanthes biflora	7.9	tr	0.0	0.0	tr	1	0	0	1	tr	0.0	0.0	0.0	1	0	0	0
Tephrosia onobrychoides	1.5	0.1	tr	0.0	tr	3	1	0	1	0.0	0.0	0.0	tr	0	0	0	1
T. virginiana	0.6	tr	0.0	0.0	0.0	3	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Unknown forbs		tr	0.0	0.0	tr					0.0	0.0	0.0	tr				
Vernonia texana	5.9	0.2	0.0	0.0	0.1	2	0	0	2	tr	0.0	0.0	0.1	2	0	0	2
Viola spp.	0.7	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	2
Subtotals		7.7	7.8	13.2	7.5					1.0	0.2	0.1	6.7				
Fecal Pellets																	
Deer		0.1	0.0	tr	0.0					0.0	0.0	0.0	0.0				
Rabbits		0.0	0.0	tr	0.0					0.0	0.0	0.0	0.0				
Fungi		0.4	2.4	0.6	0.4					0.2	0.2	tr	0.0				

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[1] Botanical composition values are percentages of seasonal bite-count totals.

[2] See appendix 3 for a cross-reference of scientific and common names.

[3] Percent frequency of occurrence on an average of 194 quadrats of 0.89 m^2 measured during June 1979 and July 1980, averaged across years.

[4] SU = summer, FA = fall, WI = winter, SP = spring.

[5] A selectivity rating of 0 indicates no seasonal use; 5 indicates highest selectivity category—i.e., within the top 20% of all species eaten during that season.

[6] tr = < 0.1%.

[7] Frequency of occurrence data not collected; therefore, selectivity ratings were not computed.

[8] Low panicum grasses which produce winter basal rosettes.

Appendix 2

Seasonal composition of cattle and tame deer diets, percent frequency of occurrence of forages, and relative forage selectivity ratings on two recently clearcut pine-hardwood sites in central Louisiana.[1]

Species[2]	% Freq.[3]	Deer								Cattle							
		% Diet composition				Selectivity[5]				% Diet composition				Selectivity			
		SU	FA	WI	SP[4]	SU	FA	WI	SP	SU	FA	WI	SP	SU	FA	WI	SP
Woody Plants																	
Acer rubrum	5.3	0.1	0.1	0.1	0.6	2	2	2	3	tr[6]	0.1	0.0	0.2	1	2	0	4
Ampelopsis arborea	0.4	0.1	0.0	0.0	0.2	4	0	0	4	0.0	0.0	0.0	0.0	0	0	0	0
Aralia spinosa	1.0	0.1	tr	0.0	0.0	3	1	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Ascyrum hypericoides	0.6	0.1	tr	0.1	tr	3	2	3	2	0.0	0.0	0.0	0.0	0	0	0	0
A. stans	0.2	tr	tr	tr	0.0	3	4	3	0	0.0	0.0	0.0	0.0	0	0	0	0
Baccharis halimifolia	7.3	0.6	2.1	6.5	1.9	3	4	5	4	0.2	1.8	4.0	0.3	3	4	5	4
Berchemia scandens	1.9	5.2	2.6	0.0	0.8	5	5	0	5	0.0	0.0	0.0	tr	0	0	0	2
Bignonia capreolata	7.4	1.0	1.0	1.3	0.3	4	4	4	2	tr	tr	tr	tr	1	1	1	1
Callicarpa americana	14.8	0.2	5.9	0.1	0.1	1	5	1	1	tr	0.8	tr	0.1	1	3	1	2
Campsis radicans	0.2	tr	tr	0.0	tr	4	3	0	4	0.0	0.0	0.0	0.0	0	0	0	0
Carpinus caroliniana	1.2	0.5	0.1	0.1	1.1	5	3	3	5	tr	0.0	0.0	0.1	2	0	0	4
Carya cordiformis	0.0	0.1	0.0	0.0	0.0	5	0	0	0	0.1	0.0	0.0	0.0	5	0	0	0
C. tomentosa	1.4	tr	0.1	tr	0.2	2	3	2	4	0.0	0.0	0.0	0.1	0	0	0	4
Cercis canadensis	0.0	0.1	0.0	0.0	0.0	5	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Chionanthus virginicus	0.3	0.1	0.1	0.0	0.4	5	4	0	5	0.0	tr	0.0	0.0	0	3	0	0
Cornus florida	0.3	0.2	0.1	0.1	0.3	5	5	4	5	0.0	0.0	0.0	0.1	0	0	0	5
Crataegus crus-galli	6.4	2.7	1.1	tr	8.8	5	4	1	5	tr	tr	0.0	0.1	1	1	0	2
C. marshallii	4.3	1.0	0.1	0.0	3.9	4	2	0	5	0.0	0.0	0.0	tr	0	0	0	2
C. spathulata	1.2	0.3	tr	tr	2.3	4	2	2	5	0.0	0.0	0.0	tr	0	0	0	2
Diospyros virginiana	17.9	0.5	0.4	0.7	0.3	2	2	2	2	0.0	0.0	0.0	tr	0	0	0	1
Fagus grandifolia	0.0	0.0	0.0	0.1	tr	0	0	5	4	0.0	0.0	0.0	tr	0	0	0	3
Fraxinus pennsylvanica	0.9	0.1	0.1	0.0	0.2	4	3	0	4	0.0	0.0	0.0	tr	0	0	0	2
Gelsemium sempervirens	9.6	1.0	7.1	15.9	0.2	3	5	5	2	0.0	0.0	0.3	tr	0	0	2	1
Gleditsia triacanthos	0.0	0.0	0.0	0.0	tr	0	0	0	4	0.0	0.0	0.0	0.0	0	0	0	0
Hamamelis virginiana	0.4	tr	tr	0.0	0.1	3	3	0	4	0.0	0.0	0.0	0.0	0	0	0	0
Ilex decidua	1.9	3.6	1.7	tr	4.7	5	5	1	5	tr	0.0	0.0	tr	1	0	0	2
I. opaca	0.2	0.0	0.0	tr	0.0	0	0	3	0	0.0	0.0	0.0	tr	0	0	0	3
I. vomitoria	0.0	0.2	0.6	0.6	tr	5	5	5	4	0.0	0.0	0.0	0.0	0	0	0	0
Liquidambar styraciflua	9.6	0.9	2.7	3.0	2.5	3	4	4	4	tr	0.5	0.0	1.0	1	3	0	4
Lonicera japonica	0.0	2.0	9.4	12.1	3.6	5	5	5	5	0.0	0.0	0.0	tr	0	0	0	5
L. sempervirens	0.0	0.2	0.0	0.0	0.1	5	0	0	5	0.0	0.0	0.0	0.0	0	0	0	0
Morus rubra	0.6	0.0	0.1	0.0	tr	0	4	0	3	0.0	0.0	0.0	tr	0	0	0	1
Myrica cerifera	2.3	0.1	1.0	9.6	0.1	2	5	5	3	0.0	tr	1.4	0.0	0	2	5	0
Nyssa sylvatica	5.7	9.8	3.8	0.4	7.6	5	5	3	5	0.7	0.5	0.0	0.6	4	4	0	4
Ostrya virginiana	0.5	0.1	0.1	tr	0.2	4	4	2	4	0.0	0.0	0.0	tr	0	0	0	4
Parthenocissus quinquefolia	1.9	0.1	0.0	0.0	0.3	3	0	0	4	0.0	0.0	0.0	tr	0	0	0	1
Pinus echinata	0.0	tr	0.0	0.0	0.0	2	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0
P. taeda	44.8	0.5	0.4	2.8	0.1	1	1	2	1	0.0	0.2	0.7	tr	0	2	2	1
Prunus mexicana	2.5	1.4	0.1	0.0	1.6	5	2	0	5	tr	tr	0.0	tr	2	1	0	3
P. serotina	1.4	0.1	0.1	0.1	0.5	2	3	2	4	0.0	tr	0.0	tr	0	3	0	2
Quercus alba	0.4	0.1	0.2	0.2	0.2	4	5	4	5	tr	tr	tr	0.1	3	3	3	5
Q. falcata	18.0	0.3	0.6	1.2	0.6	1	2	3	2	tr	0.1	0.4	0.5	1	1	2	3

Species[2]	% Freq.[3]	Deer								Cattle							
		% Diet composition				Selectivity[5]				% Diet composition				Selectivity			
		SU	FA	WI	SP[4]	SU	FA	WI	SP	SU	FA	WI	SP	SU	FA	WI	SP
Q. falcata var. *pagodifolia*	0.0	0.0	0.0	tr	0.0	0	0	5	0	0.0	0.0	0.0	0.0	0	0	0	0
Q. laurifolia	0.0	tr	0.0	0.0	0.2	4	0	0	5	tr	tr	0.0	0.1	4	4	0	5
Q. marilandica	0.3	0.0	tr	0.1	tr	0	3	4	3	0.0	0.0	0.0	0.1	0	0	0	5
Q. nigra	1.8	0.8	0.8	3.2	1.4	5	5	5	5	0.1	0.1	0.3	0.2	4	3	4	4
Q. phellos	0.0	0.0	0.0	0.0	0.1	0	0	0	5	0.0	0.0	0.0	tr	0	0	0	3
Q. stellata	8.1	0.5	0.6	2.3	1.4	3	3	4	4	0.1	0.2	0.7	2.5	2	2	3	5
Q. velutina	1.4	tr	0.1	0.2	0.4	2	2	3	4	tr	0.0	tr	0.3	3	0	2	5
Rhododendron nudiflorum	0.0	0.0	tr	0.0	0.0	0	3	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Rhus copallina	7.5	0.2	0.4	1.9	0.6	2	3	4	3	0.0	0.0	0.0	0.2	0	0	0	3
Rubus spp.	59.1	8.6	18.7	18.3	11.9	4	4	4	4	tr	0.2	0.3	2.0	1	1	1	4
Salix nigra	0.0	tr	0.1	0.1	0.1	4	5	5	5	0.0	0.0	0.0	0.0	0	0	0	0
Sambucus canadensis	1.1	0.2	0.0	0.2	0.2	4	0	4	4	tr	0.0	0.0	0.1	1	0	0	4
Smilax bona-nox	13.4	4.4	5.1	1.8	7.0	4	5	3	5	0.1	0.2	tr	0.3	2	2	1	3
S. glauca	5.1	3.2	1.9	2.7	0.5	5	4	5	3	0.0	0.1	tr	tr	0	2	2	1
S. hispida	0.2	tr	0.0	0.0	tr	3	0	0	4	0.0	0.0	0.0	tr	0	0	0	3
S. rotundifolia	3.4	2.3	0.7	0.1	2.6	5	4	2	5	0.1	tr	0.0	0.1	3	2	0	3
S. smallii	0.0	0.0	tr	1.0	0.0	0	3	5	0	0.0	0.0	tr	0.0	0	0	4	0
Styrax grandifolia	0.0	tr	0.0	0.0	0.2	3	0	0	5	0.0	0.0	0.0	0.0	0	0	0	0
Symplocos tinctoria	0.2	tr	0.0	0.0	0.1	4	0	0	5	0.0	0.0	0.0	tr	0	0	0	4
Toxicodendron radicans	19.8	1.1	0.1	0.0	1.7	3	1	0	3	0.0	0.0	0.0	0.1	0	0	0	2
T. toxicarium	0.2	0.0	0.0	0.0	tr	0	0	0	3	0.0	0.0	0.0	tr	0	0	0	3
Trachelosperum difforme	4.5	2.8	1.0	0.0	0.4	5	4	0	3	tr	tr	0.0	tr	2	1	0	1
Ulmus alata	4.6	4.8	1.8	0.0	4.7	5	5	0	5	tr	0.0	0.0	0.2	1	0	0	4
Vaccinium arboreum	2.8	0.7	0.9	0.6	1.5	4	4	4	5	0.0	0.0	0.0	0.2	0	0	0	4
V. caesium	0.0	0.0	tr	0.0	0.0	0	5	0	0	0.0	0.0	0.0	0.0	0	0	0	0
V. corymbosum and *V. stamineum*	10.8	0.7	0.5	0.9	0.7	3	2	3	3	0.0	0.0	0.0	0.6	0	0	0	4
V. elliottii	0.7	0.1	0.2	tr	0.6	3	4	2	5	tr	0.0	0.0	tr	2	0	0	3
Viburnum dentatum	1.1	1.6	0.7	0.0	6.2	5	5	0	5	tr	0.0	0.0	tr	3	0	0	4
V. rufidulum	0.3	tr	0.0	0.0	tr	2	0	0	2	0.0	0.0	0.0	0.0	0	0	0	0
Vitis aestivalis	1.2	1.3	0.3	0.0	0.2	5	4	0	4	0.0	0.0	0.0	0.0	0	0	0	0
V. rotundifolia	9.1	1.4	1.1	0.2	1.3	4	3	2	4	0.0	0.1	0.0	tr	0	2	0	1
Yucca spp.	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	tr	0.0	0	0	4	0
Subtotals		68.1	76.7	88.7	87.8					1.5	4.9	8.3	10.7				
Grasses																	
Andropogon elliottii	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.2	tr	tr	0	5	3	5
A. gerardii	3.7	1.1	0.1	0.0	0.4	4	2	0	3	11.8	7.5	0.2	2.7	5	5	3	5
A. glomeratus	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.1	0.1	0.0	0	5	5	0
A. subtenuis	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	tr	0.0	0.0	0	4	0	0
A. virginicus	25.4	1.2	0.2	tr	0.1	2	1	1	1	3.5	4.0	2.0	0.5	4	4	3	3
Aristida purpurascens	4.4	tr	0.0	0.0	0.0	1	0	0	0	0.1	0.1	0.0	0.0	3	2	0	0
Arundinaria gigantea	4.6	0.3	0.7	2.1	0.1	3	4	4	2	tr	0.0	0.4	tr	2	0	4	2

Species[2]	% Freq.[3]	Deer								Cattle							
		% Diet composition				Selectivity[5]				% Diet composition				Selectivity			
		SU	FA	WI	SP[4]	SU	FA	WI	SP	SU	FA	WI	SP	SU	FA	WI	SP
Axonopus affinis	5.1	0.2	0.0	0.0	0.0	2	0	0	0	8.4	12.9	3.0	0.2	5	5	5	4
Chasmanthium laxum and *C. sessiliflorum*	70.1	1.5	0.2	0.1	1.1	2	1	1	2	14.2	16.0	16.4	24.0	4	4	4	5
Cynodon dactylon	0.3	0.1	0.0	0.0	0.0	4	0	0	0	0.8	0.5	0.0	tr	5	5	0	2
Dichanthelium spp.[7]	96.0	3.4	1.3	1.4	2.7	2	1	2	2	14.0	21.0	25.4	35.2	4	4	4	5
D. scoparium	0.7	0.2	0.2	0.0	tr	4	4	0	2	0.0	0.7	0.8	0.2	0	5	5	5
Digitaria ischaemum var. *violascens*	0.3	0.3	0.0	0.0	0.0	5	0	0	0	0.2	2.2	0.0	0.0	5	5	0	0
D. villosa	0.9	0.6	0.1	0.0	0.0	5	3	0	0	1.1	0.3	0.0	0.0	5	4	0	0
Eragrostis spectabilis	0.0	0.0	0.0	0.0	0.0	0	0	0	0	tr	0.0	0.0	0.0	3	0	0	0
Erianthus contortus	1.0	0.1	0.1	0.0	0.0	3	3	0	0	0.2	0.8	tr	tr	4	5	2	3
Gymnopogon ambiguus and *G. brevifolius*	1.7	2.3	0.3	tr	0.0	5	4	2	0	0.1	0.1	0.0	tr	3	4	0	1
Melica mutica	0.2	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	5
Panicum anceps var. *rhizomatum*	10.9	0.4	0.3	0.0	0.1	2	2	0	1	4.5	2.2	0.7	0.9	5	4	3	4
P. virgatum	0.2	tr	0.0	0.0	0.0	4	0	0	0	0.1	0.0	0.0	0.1	5	0	0	5
Paspalum spp.	[8]	tr	0.0	0.0	0.0					0.0	0.0	0.0	0.0				
P. dilatatum	1.1	0.5	0.1	0.0	0.0	5	3	0	0	1.4	0.5	0.0	tr	5	5	0	2
P. floridanum	4.2	0.1	0.2	0.0	0.0	2	3	0	0	2.3	0.1	0.0	0.0	5	3	0	0
P. laeve var. *circulare*	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.2	0.1	0.0	0.0	5	5	0	0
P. minus	0.2	0.0	0.0	0.0	0.0	0	0	0	0	tr	tr	0.0	0.0	4	3	0	0
P. notatum	0.3	tr	tr	0.0	0.0	2	3	0	0	1.6	0.7	0.0	0.0	5	5	0	0
P. plicatulum	9.8	0.7	0.1	0.0	0.2	3	1	0	2	5.6	1.3	0.1	0.6	5	4	2	4
P. setaceum var. *ciliatifolium*	0.3	0.0	0.0	0.0	tr	0	0	0	2	0.3	0.0	0.0	tr	5	0	0	4
P. setaceum var. *muhlenbergii*	5.3	0.1	0.0	0.0	0.1	1	0	0	1	tr	0.0	0.0	tr	1	0	0	1
P. urvillei	0.2	tr	0.1	0.0	tr	4	5	0	4	2.4	2.4	0.0	tr	5	5	0	5
Schizachyrium scoparium var. *divergens*	19.6	0.2	0.1	tr	0.5	1	1	1	2	7.5	13.2	2.8	5.0	4	5	4	5
Setaria glauca	0.3	tr	0.0	tr	0.0	1	0	3	0	0.0	0.0	0.1	0.0	0	0	4	0
Sorghastrum nutans	0.3	0.0	tr	0.0	0.0	0	2	0	0	0.2	0.4	0.0	tr	5	5	0	3
Steinchisma hians	0.2	tr	0.0	0.0	0.0	2	0	0	0	0.1	0.1	0.0	0.0	5	5	0	0
Stipa avenacea	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	0.1	0	0	0	5
Tridens flavus	1.1	0.1	tr	0.0	0.0	3	1	0	0	0.2	0.1	0.0	tr	4	4	0	2
Subtotals		13.5	4.3	3.8	5.3					80.8	87.3	51.8	69.6				
Grasslike Plants																	
Carex complanata	40.0	tr	0.0	0.0	0.1	1	0	0	1	0.3	0.4	3.2	1.1	2	2	3	3
C. flaccosperma	14.0	0.5	0.1	0.2	0.2	2	1	2	2	tr	0.1	1.3	0.7	1	2	3	4
C. vulpinoidea	0.3	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	0.1	0	0	0	5
Cyperus esculentus	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	4
C. ovularis	0.9	0.0	0.0	0.0	0.0	0	0	0	0	tr	0.0	0.0	0.0	2	0	0	0

Species[2]	% Freq.[3]	Deer								Cattle							
		% Diet composition				Selectivity[5]				% Diet composition				Selectivity			
		SU	FA	WI	SP[4]	SU	FA	WI	SP	SU	FA	WI	SP	SU	FA	WI	SP
C. virens	1.4	tr	0.0	0.0	0.0	1	0	0	0	tr	0.0	0.0	0.0	3	0	0	0
Eleocharis spp.		0.0	0.0	0.0	tr					0.0	0.0	0.3	0.1				
E. obtusa	0.0	0.0	0.0	0.0	0.0	0	0	0	0	tr	0.0	0.0	0.0	4	0	0	0
Juncus effusus	0.9	0.0	0.0	tr	0.0	0	0	2	0	tr	0.1	0.5	0.1	3	3	5	4
J. scirpoides	0.5	0.0	0.0	0.0	0.1	0	0	0	3	0.0	0.0	0.0	0.0	0	0	0	0
J. tenuis	11.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	0.3	0	0	0	3
J. validus	4.9	0.1	tr	tr	0.3	1	1	1	3	tr	0.0	tr	0.6	2	0	1	5
Rhynchospora globularis and *R. glomerata*	20.1	0.1	0.0	tr	0.0	1	0	1	0	0.4	0.2	tr	0.2	3	2	1	2
R. inexpansa	39.6	0.1	tr	0.0	0.3	1	1	0	1	1.3	1.7	12.1	5.4	3	3	5	5
Scirpus cyperinus	0.2	tr	0.0	tr	0.0	4	0	3	0	0.1	0.1	tr	0.1	5	5	3	5
Scleria oligantha	58.2	0.1	0.0	0.1	tr	1	0	1	1	0.7	1.3	21.2	6.9	2	3	5	4
Subtotals		1.0	0.1	0.4	0.9					2.8	3.9	38.8	15.6				
Forbs and Ferns																	
Acalypha gracilens	5.6	0.1	0.2	0.0	0.0	1	2	0	0	0.0	tr	0.0	0.0	0	1	0	0
Agalinis purpurea	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	tr	0.0	0	0	4	0
Ageratina altissima	0.4	0.8	1.1	0.1	0.3	5	5	3	5	0.0	0.0	tr	tr	0	0	2	3
Ambrosia artemisiifolia	0.0	tr	0.1	0.0	0.0	4	5	0	0	tr	0.0	0.0	0.0	4	0	0	0
Aristolochia serpentaria	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	3
Asclepias variegata	0.0	tr	0.0	0.0	0.0	2	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Aster dumosus	18.4	1.2	0.4	tr	0.1	3	2	1	1	tr	tr	tr	tr	1	1	1	1
A. patens	7.6	tr	0.1	0.0	tr	1	1	0	1	0.0	0.0	0.0	tr	0	0	0	1
Baptisia nuttalliana	0.7	tr	0.0	0.1	0.0	1	0	3	0	0.0	0.0	0.0	0.0	0	0	0	0
Boltonia diffusa	3.1	tr	0.3	0.0	0.0	1	3	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Cassia fasciculata	2.6	0.4	tr	0.0	0.0	4	1	0	0	0.5	0.0	0.0	0.0	4	0	0	0
Centrosema virginianum	0.3	0.1	0.0	0.0	tr	4	0	0	3	tr	0.0	0.0	0.0	3	0	0	0
Conoclinium coelestinum	1.3	0.2	1.1	0.0	0.0	4	5	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Conyza canadensis	0.3	0.2	0.0	0.0	tr	5	0	0	2	0.0	0.0	0.0	0.1	0	0	0	5
Coreopsis lanceolata	0.0	0.0	0.0	0.0	tr	0	0	0	3	0.0	0.0	0.0	0.0	0	0	0	0
Crotalaria sagittalis	0.0	0.0	0.0	0.0	0.0	0	0	0	0	tr	0.0	0.0	0.0	3	0	0	0
Croton capitatus	0.0	0.0	0.0	0.0	0.0	0	0	0	0	tr	0.0	0.0	0.0	3	0	0	0
Cynoctonum mitreola	0.0	0.0	tr	0.0	0.0	0	3	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Desmodium spp.	4.3	0.6	0.2	0.0	0.2	4	2	0	3	tr	0.0	0.0	tr	1	0	0	1
D. dillenii	0.0	0.1	tr	0.0	tr	5	4	0	4	0.0	0.0	0.0	0.0	0	0	0	0
D. paniculatum	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	3
D. rigidum	1.6	0.2	0.0	0.0	0.0	4	0	0	0	0.1	0.0	0.0	0.0	4	0	0	0
D. rotundifolium	0.0	tr	0.0	0.0	0.0	3	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Dichondra carolinensis	3.4	0.0	0.2	0.0	0.1	0	2	0	2	0.0	0.0	0.0	0.0	0	0	0	0
Diodia teres	1.3	0.2	tr	0.0	0.0	4	2	0	0	0.5	0.0	0.0	0.0	5	0	0	0
Elephantopus tomentosus	0.3	tr	0.0	0.0	0.0	4	0	0	0	0.0	0.0	tr	0.0	0	0	2	0
Erigeron philadelphicus	0.0	0.0	0.0	0.2	0.4	0	0	5	5	0.0	0.0	0.0	0.0	0	0	0	0
E. strigosus	0.0	0.0	0.0	0.0	tr	0	0	0	3	0.0	0.0	0.0	0.0	0	0	0	0
Eryngium prostratum	1.9	tr	0.0	0.0	0.0	1	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0

Species[2]	% Freq.[3]	Deer								Cattle							
		% Diet composition				Selectivity[5]				% Diet composition				Selectivity			
		SU	FA	WI	SP[4]	SU	FA	WI	SP	SU	FA	WI	SP	SU	FA	WI	SP
E. yuccifolium	0.0	0.1	0.0	0.0	tr	5	0	0	3	0.0	0.0	0.0	tr	0	0	0	5
Eupatorium spp.		0.0	0.0	0.0	tr					0.0	0.0	0.0	0.0				
E. capillifolium	21.2	tr	0.0	0.1	0.0	1	0	1	0	0.0	tr	0.0	0.1	0	1	0	1
E. compositifolium	0.2	tr	0.0	0.0	0.0	4	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0
E. perfoliatum	1.3	0.0	0.0	0.1	tr	0	0	3	2	0.0	0.0	0.0	tr	0	0	0	1
E. rotundifolium	2.4	0.0	0.0	0.0	tr	0	0	0	1	0.0	0.0	0.0	tr	0	0	0	2
E. semiserratum	0.0	0.0	0.0	0.1	0.0	0	0	5	0	0.0	0.0	0.0	tr	0	0	0	3
Euphorbia corollata	1.2	tr	0.0	0.0	tr	2	0	0	1	0.0	0.0	0.0	tr	0	0	0	2
E. maculata	0.6	tr	tr	0.0	0.0	2	3	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Euthamia leptocephala	3.3	0.2	0.2	0.0	tr	2	2	0	1	0.0	0.1	0.0	tr	0	2	0	2
Galactia volubilis	4.3	0.8	0.1	0.0	0.0	4	1	0	0	0.1	tr	0.0	0.0	2	1	0	0
Galium pilosum	0.4	tr	tr	0.0	0.0	3	2	0	0	tr	0.0	0.0	tr	3	0	0	3
Gamochaeta falcata	0.7	0.0	0.0	0.1	0.0	0	0	4	0	0.0	0.0	0.0	0.0	0	0	0	0
G. purpurea	15.7	0.1	0.3	0.3	0.2	1	2	2	1	0.0	0.0	0.3	tr	0	0	2	1
Geranium dissectum	0.0	0.0	0.0	0.0	0.1	0	0	0	5	0.0	0.0	0.0	0.0	0	0	0	0
Helenium flexuosum	3.7	0.0	0.0	0.0	tr	0	0	0	1	tr	0.0	0.0	0.0	2	0	0	0
Helianthus angustifolius	4.5	0.1	0.3	0.0	0.1	2	3	0	2	0.1	0.1	0.0	0.1	3	3	0	2
H. hirsutus	11.9	tr	0.0	0.0	tr	1	0	0	1	tr	0.0	0.0	0.3	1	0	0	3
Heterotheca graminifolia	4.7	tr	0.1	0.0	0.1	1	1	0	1	0.1	tr	0.0	tr	2	1	0	1
H. pilosa	0.2	0.0	tr	0.0	0.0	0	3	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Hypericum drummondii	0.0	tr	0.0	0.1	0.0	3	0	5	0	0.0	0.0	0.0	0.0	0	0	0	0
Ipomoea spp.	0.0	tr	0.0	0.0	0.0	2	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Krigia dandelion	0.3	0.0	0.0	0.0	0.1	0	0	0	4	0.0	0.0	0.0	tr	0	0	0	3
Lechea villosa	0.0	tr	0.2	0.0	0.0	3	5	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Lespedeza hirta	0.2	tr	tr	0.0	0.0	3	4	0	0	0.0	0.0	0.0	0.0	0	0	0	0
L. procumbens and *L. repens*	7.5	1.4	0.4	0.0	0.9	4	3	0	3	3.3	1.3	0.0	0.9	5	4	0	4
L. striata	5.7	5.0	4.9	0.0	0.4	5	5	0	3	9.4	1.4	0.0	0.4	5	4	0	4
L. violacea	3.1	0.1	0.0	0.0	tr	2	0	0	1	0.0	0.0	0.0	0.4	0	0	0	5
L. virginica	4.3	0.2	0.2	0.0	0.1	2	3	0	1	0.1	0.0	0.0	tr	2	0	0	1
Liatris spp.	0.2	tr	0.0	0.0	0.1	3	0	0	4	0.0	0.0	0.0	0.3	0	0	0	5
L. pycnostachya	0.0	0.0	0.0	0.0	tr	0	0	0	4	0.0	0.0	0.0	0.0	0	0	0	0
Lobelia puberula	0.6	0.0	tr	0.0	0.0	0	2	0	0	tr	0.1	0.0	0.0	2	4	0	0
Ludwigia alternifolia	6.1	1.6	tr	tr	0.4	4	1	1	3	0.1	0.0	0.0	tr	2	0	0	1
L. decurrens	0.0	tr	0.0	0.0	0.0	2	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0
L. glandulosa	0.6	0.4	tr	0.0	tr	5	2	0	3	0.1	0.0	0.0	tr	4	0	0	4
Mecardonia acuminata	9.3	tr	0.2	4.0	tr	1	2	4	1	0.3	0.5	0.7	tr	3	3	3	1
Mitchella repens	0.2	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	3
Monarda fistulosa	0.4	0.0	0.0	tr	0.0	0	0	3	0	0.0	0.0	0.0	tr	0	0	0	2
Oxalis stricta	12.0	tr	0.1	tr	0.2	1	1	1	2	0.0	0.0	0.0	tr	0	0	0	1
O. violacea	0.0	tr	0.0	0.0	0.0	2	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Passiflora incarnata	0.0	0.0	0.0	0.0	0.0	0	0	0	0	tr	0.0	0.0	0.0	4	0	0	0
P. lutea	0.3	tr	0.0	0.0	tr	3	0	0	4	tr	0.1	0.0	tr	2	5	0	3

Species[2]	% Freq.[3]	Deer								Cattle							
		% Diet composition				Selectivity[5]				% Diet composition				Selectivity			
		SU	FA	WI	SP[4]	SU	FA	WI	SP	SU	FA	WI	SP	SU	FA	WI	SP
Penthorum sedoides	0.0	tr	0.0	0.0	0.0	3	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Phlox pilosa	0.5	0.0	0.0	0.0	tr	0	0	0	2	0.0	0.0	0.0	tr	0	0	0	2
Phytolacca americana	0.0	0.1	tr	0.0	0.0	5	4	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Plantago aristata	1.6	0.0	0.0	0.0	tr	0	0	0	2	tr	0.0	0.0	tr	1	0	0	2
Polygala chapmanii	0.0	tr	0.0	0.0	0.0	3	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0
P. polygama	1.3	tr	0.0	0.0	0.0	1	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Polypremum procumbens	0.0	0.1	0.0	0.0	0.0	5	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Potentilla simplex	0.0	0.1	0.0	0.0	0.0	5	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Prunella vulgaris	5.4	tr	0.0	0.0	0.3	1	0	0	3	0.0	0.0	tr	tr	0	0	1	2
Pteridium aquilinum var. *pseudocaudatum*	1.7	tr	0.0	tr	tr	2	0	2	2	0.0	0.0	0.0	0.3	0	0	0	5
Pycnanthemum albescens	2.7	tr	0.0	0.0	tr	1	0	0	1	0.0	0.0	0.0	tr	0	0	0	1
P. tenuifolium	4.5	tr	0.0	0.0	tr	1	0	0	1	0.0	0.0	0.0	tr	0	0	0	2
Pyrrhopappus carolinianus	0.0	0.1	0.0	0.0	0.0	5	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Rhexia mariana	2.6	0.9	0.6	0.0	0.0	5	4	0	0	0.2	0.1	0.0	tr	4	3	0	1
Rudbeckia hirta	5.6	tr	tr	0.0	tr	1	1	0	1	0.0	0.0	0.0	tr	0	0	0	1
Ruellia pedunculata	2.5	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	2
Sabatia angularis	1.2	tr	0.0	0.0	0.0	2	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0
S. brachiata	0.6	tr	0.0	0.0	0.0	3	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Salvia azurea var. *grandiflora*	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	5
S. lyrata	3.4	0.0	0.0	0.0	tr	0	0	0	1	0.0	0.0	0.0	tr	0	0	0	2
Schrankia uncinata	0.7	tr	0.0	0.0	0.0	2	0	0	0	0.0	0.0	0.0	tr	0	0	0	3
Scutellaria elliptica	0.4	0.0	tr	0.0	tr	0	2	0	2	0.0	0.0	0.0	tr	0	0	0	4
S. integrifolia	19.5	tr	0.2	0.0	tr	1	1	0	1	0.0	tr	tr	0.1	0	1	1	1
Selaginella spp.	0.0	tr	0.0	0.1	0.0	4	0	5	0	0.0	0.0	0.0	0.0	0	0	0	0
Sisyrinchium spp.	0.3	0.0	0.0	0.0	tr	0	0	0	3	0.0	0.0	0.0	0.0	0	0	0	0
Solanum carolinense	3.6	0.1	tr	0.0	0.0	1	1	0	0	0.0	tr	0.0	tr	0	1	0	1
Solidago spp.	3.3	tr	0.0	0.4	tr	1	0	3	1	0.0	0.0	0.1	tr	0	0	2	2
S. altissima	12.3	0.3	5.1	1.0	0.8	2	5	3	3	0.0	tr	0.0	0.2	0	1	0	3
S. ludoviciana	0.0	tr	0.0	0.0	0.0	3	0	0	0	0.0	0.0	0.0	tr	0	0	0	5
S. odora	6.7	0.1	0.0	tr	tr	1	0	1	1	tr	tr	0.0	0.0	1	2	0	0
S. rugosa	25.0	0.4	0.1	0.1	0.4	1	1	1	2	0.0	tr	tr	0.4	0	1	1	3
Spigelia marilandica	2.4	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	tr	0	0	0	1
Stylosanthes biflora	6.4	tr	0.0	0.0	0.0	1	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0
Tephrosia onobrychoides	0.3	tr	0.0	0.0	0.0	3	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0
T. virginiana	0.9	tr	tr	0.0	tr	2	2	0	2	0.1	tr	0.0	tr	4	3	0	3
Tradescantia hirsuticaulis	0.3	0.0	0.0	0.0	tr	0	0	0	2	0.0	0.0	0.0	tr	0	0	0	2
Unknown forbs		tr	0.0	0.0	0.1					0.0	0.0	0.0	tr				
Verbena brasiliensis	0.2	tr	0.0	tr	0.0	3	0	4	0	0.0	0.0	0.0	tr	0	0	0	3
Vernonia texana	1.9	0.1	0.0	0.0	0.0	3	0	0	0	0.0	0.0	0.0	tr	0	0	0	2
Viola spp.	4.6	0.0	0.0	0.0	0.2	0	0	0	2	0.0	0.0	0.0	tr	0	0	0	1
Subtotals		17.1	14.7	6.7	5.9					14.9	3.9	1.1	4.2				

Species[2]	% Freq.[3]	Deer								Cattle							
		% Diet composition				Selectivity[5]				% Diet composition				Selectivity			
		SU	FA	WI	SP[4]	SU	FA	WI	SP	SU	FA	WI	SP	SU	FA	WI	SP
Fecal Pellets																	
Deer		0.4	tr	tr	0.1					0.0	0.0	0.0	0.0				
Rabbits		tr	0.1	0.0	0.0					0.0	0.0	0.0	0.0				
Fungi		tr	2.1	0.2	tr					0.0	0.0	0.0	0.0				

[1] Botanical composition values are percentages of seasonal bite-count totals.

[2] See appendix 3 for a cross-reference of scientific and common names.

[3] Percent frequency of occurrence on an average of 154 quadrats of 0.22 m^2 measured during June 1979 and July 1980, averaged across years.

[4] SU = summer, FA = fall, WI = winter, SP = spring.

[5] A selectivity rating of 0 indicates no seasonal use; 5 indicates highest selectivity category—i.e., within the top 20% of all species eaten during that season.

[6] tr = < 0.1%.

[7] Low panicum grasses which produce winter basal rosettes.

[8] Frequency of occurrence data not collected; therefore, selectivity ratings were not computed.

Appendix 3

Alphabetic cross-reference of scientific and common names.

Acalypha gracilens	slender copperleaf
Acer rubrum	red maple
Aesculus parviflora	red buckeye
Agalinis purpurea	purple gerardia
Agave virginica	see *Manfreda*
Ageratina altissima	white snakeroot
Aletris farinosa	whitetube stargrass
Ambrosia artemisiifolia	common ragweed
Ampelopsis arborea	peppervine
Andropogon	bluestem
divergens	see *Schizachyrium scoparium* var. *divergens*
elliottii	Elliott bluestem
gerardii	big bluestem
glomeratus	bushy bluestem
subtenuis	fineleaf bluestem
virginicus	broomsedge
Anisostichus	see *Bignonia*
Antennaria plantaginifolia	plantainleaf pussytoes
Apocynum cannabinum	hemp dogbane
Aralia spinosa	devils-walkingstick
Aristida purpurascens	arrowfeather threeawn
Aristolochia serpentaria	Virginia dutchmanspipe
arrowwood	*Viburnum dentatum*
Arundinaria gigantea	cane
Asclepias variegata	white milkweed
Ascyrum	
hypericoides	St. Andrewscross
stans	St. Peterswort
ash, green	*Fraxinus pennsylvanica*
Aster	aster
dumosus	bushy aster
patens	skydrop aster
aster	*Aster*
bushy	*A. dumosus*
skydrop	*A. patens*
Axonopus affinis	common carpetgrass
Azalea	see *Rhododendron*
azalea, wild	*Rhododendron nudiflorum*
Baccharis halimifolia	eastern baccharis
bahiagrass	*Paspalum notatum*
Baptisia nuttalliana	Nuttall wildindigo
bayberry, southern	*Myrica cerifera*
beakrush	*Rhynchospora*
cluster	*R. glomerata*
globe	*R. globularis*
nodding	*R. inexpansa*
beard-tongue	*Penstemon australis*
beautyberry, American	*Callicarpa americana*
bedstraw, hairy	*Galium pilosum*
beebalm, wild-bergamot	*Monarda fistulosa*
beech, American	*Fagus grandifolia*
Berchemia scandens	Alabama supplejack; rattan-vine
bermudagrass, common	*Cynodon dactylon*
Bignonia capreolata	crossvine
blackberry	*Rubus* spp.
black-eyed-susan	*Rudbeckia hirta*
blackgum	*Nyssa sylvatica*

blackhaw, rusty	*Viburnum rufidulum*
blueberry	*Vaccinium*
Elliott	*V. elliottii*
Florida	*V. caesium*
highbush	*V. corymbosum*
blue-eyed-grass	*Sisyrinchium* spp.
bluestem	*Andropogon*
big	*A. gerardii*
broomsedge	*A. virginicus*
bushy	*A. glomeratus*
Elliott	*A. elliottii*
fineleaf	*A. subtenuis*
pinehill	*Schizachyrium scoparium* var. *divergens*
Boltonia diffusa	smallhead boltonia
boneset	*Eupatorium perfoliatum*
bracken-fern, southern	*Pteridium aquilinum* var. *pseudocaudatum*
breweria, white	*Stylisma humistrata*
bristlegrass, yellow	*Setaria glauca*
buckeye, red	*Aesculus parviflora*
buckthorn, Carolina	*Rhamnus caroliniana*
bulrush, woolgrass	*Scirpus cyperinus*
butterflypea	*Centrosema virginianum*
button-snakeroot	*Eryngium yuccifolium*
buttonweed, rough	*Diodia teres*
Callicarpa americana	American beautyberry; French-mulberry
Campsis radicans	trumpetcreeper
cane	*Arundinaria gigantea*
Carex	sedge
complanata	blue sedge
flaccosperma	thinfruit sedge
vulpinoidea	fox sedge
carpetgrass, common	*Axonopus affinis*
Carpinus caroliniana	American hornbeam
Carya	hickory
cordiformis	bitternut hickory
tomentosa	mockernut hickory
Cassia fasciculata	showy partridgepea
Centrosema virginianum	butterflypea
Cercis canadensis	eastern redbud
Chasmanthium	uniola
laxum	spike uniola
sessiliflorum	longleaf uniola
cherry, black	*Prunus serotina*
Chionanthus virginicus	fringetree
chokecherry, flatwoods	*Prunus umbellata*
Chrysopsis	see *Heterotheca*
cinquefoil, spreading	*Potentilla simplex*
coneflower, rough	*Rudbeckia grandiflora*
Conoclinium coelestinum	mistflower eupatorium
Conyza canadensis	Canada horseweed
copperleaf, slender	*Acalypha gracilens*
Coreopsis lanceolata	thickleaf coreopsis
coreopsis, thickleaf	*Coreopsis lanceolata*
Cornus florida	flowering dogwood
crabgrass	*Digitaria*
shaggy	*D. villosa*
violet	*D. ischaemum* var. *violascens*

Crataegus	hawthorn
crus-galli	cockspur hawthorn
marshallii	parsley hawthorn
pyracanthoides	see *C. crus-galli*
spathulata	littlehip hawthorn
creeper, Virginia	*Parthenocissus quinquefolia*
crossvine	*Bignonia capreolata*
Crotalaria sagittalis	arrow crotalaria
Croton capitatus	woolly croton
croton, woolly	*Croton capitatus*
cudweed, purple	*Gamochaeta purpurea*
Cynoctonum mitreola	lax hornpod
Cynodon dactylon	common bermudagrass
Cyperus	flatsedge
esculentus	chufa flatsedge
ovularis	globe flatsedge
virens	green flatsedge
dallisgrass	*Paspalum dilatatum*
deerberry, common	*Vaccinium stamineum*
Desmodium	tickclover
ciliare	littleleaf tickclover
dillenii	Dillen tickclover
paniculatum	panicled tickclover
rigidum	rigid tickcover
rotundifolium	roundleaf tickclover
devils-walkingstick	*Aralia spinosa*
dewberry	*Rubus* spp.
Dichanthelium spp.	"low" panicums
scoparium	velvet panicum
Dichondra carolinensis	ponyfoot
Digitaria	crabgrass
ischaemum var. *violascens*	violet crabgrass
villosa	shaggy crabgrass
violascens	see *D. ischaemum* var. *violascens*
Diodia teres	rough buttonweed; poor-joe
Diospyros virginiana	common persimmon
dogbane, hemp	*Apocynum cannabinum*
dogwood, flowering	*Cornus florida*
dwarf-dandelion, tuber	*Krigia dandelion*
Duchesnea indica	India mockstrawberry
dutchmanspipe, Virginia	*Aristolochia serpentaria*
elder, American	*Sambucus canadensis*
Eleocharis obtusa	blunt spikerush
elephantfoot, hairy	*Elephantopus tomentosus*
Elephantopus tomentosus	hairy elephantfoot
elm, winged	*Ulmus alata*
Eragrostis spectabilis	purple lovegrass
Erianthus contortus	bent-awn plumegrass
Erigeron	fleabane
canadensis	see *Conyza canadensis*
philadelphicus	Philadelphia fleabane
strigosus	daisy fleabane
Eryngium	eryngo
prostratum	creeping eryngo
yuccifolium	button-snakeroot
eryngo, creeping	*Eryngium prostratum*

Eupatorium	eupatorium
album	white eupatorium
capillifolium	dogfennel
coelestinum	see *Conoclinium coelestinum*
compositifolium	yankeeweed
perfoliatum	boneset
pubescens	see *E. rotundifolium* var. *ovatum*
rotundifolium	roundleaf eupatorium
rugosum	see *Ageratina altissima*
semiserratum	smallflower eupatorium
eupatorium	*Eupatorium*
boneset	*E. perfoliatum*
dogfennel	*E. capillifolium*
mistflower	*Conoclinium coelestinum*
roundleaf	*Eupatorium rotundifolium*
smallflower	*E. semiserratum*
yankeeweed	*E. compositifolium*
white	*E. album*
Euphorbia	spurge
corollata	flowering spurge
maculata	spotted spurge
Euthamia leptocephala	slimhead goldenrod
Fagus grandifolia	American beech
false-aloe	*Manfreda virginica*
false-dandelion, Carolina	*Pyrrhopappus carolinianus*
farkleberry	*Vaccinium arboreum*
fern	see *Pteridium aquilinum* var. *pseudocaudatum* or *Polypodium polypodioides*
flatsedge	*Cyperus*
chufa	*C. esculentus*
globe	*C. ovularis*
green	*C. virens*
fleabane	*Erigeron*
daisy	*E. strigosus*
Philadelphia	*E. philadelphicus*
flax, woodland	*Linum virginianum*
Fraxinus pennsylvanica	green ash
French-mulberry	*Callicarpa americana*
fringetree	*Chionanthus virginicus*
Galactia volubilis	downy milkpea
Galium pilosum	hairy bedstraw
Gamochaeta	cudweed
falcata	cudweed
purpurea	purple cudweed
gayfeather	*Liatris*
Kansas	*L. pycnostachya*
Ontario	*L. cylindracea*
Gelsemium sempervirens	Carolina jessamine; yellow jessamine
Geranium dissectum	cutleaf geranium
geranium, cutleaf	*Geranium dissectum*
Gerardia	see *Agalinis*
gerardia, purple	*Agalinis purpurea*
Gleditsia triacanthos	honeylocust
Gnaphalium	cudweed
falcatum	see *Gamochaeta falcata*
purpureum	see *Gamochaeta purpurea*

goldaster	*Heterotheca*
grassleaf	*H. graminifolia*
soft	*H. pilosa*
goldenrod	*Solidago*
fragrant	*S. odora*
Louisiana	*S. ludoviciana*
shiny	*S. nitida*
slimhead	*Euthamia leptocephala*
tall	*Solidago altissima*
wrinkled	*S. rugosa*
grape	*Vitis*
muscadine	*V. rotundifolia*
summer	*V. aestivalis*
greenbrier	*Smilax*
bristly	*S. hispida*
cat	*S. glauca*
common	*S. rotundifolia*
saw	*S. bona-nox*
Small	*S. smallii*
Gymnopogon	skeletongrass
ambiguus	bearded skeletongrass
brevifolius	slim skeletongrass
Halesia diptera	two-wing silverbell
Hamamelis virginiana	witch-hazel
hawkweed	*Hieracium gronovii*
hawthorn	*Crataegus*
cockspur	*C. crus-galli*
littlehip	*C. spathulata*
parsley	*C. marshallii*
Helenium	sneezeweed
flexuosum	purplehead sneezeweed
nudiflorum	see *H. flexuosum*
Helianthus	sunflower
angustifolius	swamp sunflower
hirsutus	hairy sunflower
Heterotheca	goldaster
graminifolia	grassleaf goldaster
pilosa	soft goldaster
hickory	*Carya*
bitternut	*C. cordiformis*
mockernut	*C. tomentosa*
Hieracium gronovii	hawkweed
holly, American	*Ilex opaca*
honeylocust	*Gleditsia triacanthos*
honeysuckle	*Lonicera*
Japanese	*L. japonica*
trumpet	*L. sempervirens*
hophornbeam, eastern	*Ostrya virginiana*
hornbeam, American	*Carpinus caroliniana*
hornpod, lax	*Cynoctonum mitreola*
horseweed, Canada	*Conyza canadensis*
hurrahgrass	*Paspalum setaceum* var. *muhlenbergii*
Hypericum	St. Johnswort
drummondii	Drummond St. Johnswort
hypericoides	see *Ascyrum hypericoides*
stans	see *Ascyrum stans*

Ilex	holly
decidua	possumhaw
opaca	American holly
vomitoria	yaupon
indiangrass, yellow	*Sorghastrum nutans*
Ipomoea spp.	morningglory
ironweed, Texas	*Vernonia texana*
jessamine, Carolina	*Gelsemium sempervirens*
Juncus	rush
effusus	common rush
scirpoides	needlepod rush
tenuis	poverty rush
validus	roundhead rush
juniperleaf	*Polypremum procumbens*
Jussiaea decurrens	see *Ludwigia decurrens*
Krigia dandelion	tuber dwarf-dandelion
Lactuca spp.	lettuce
Lechea villosa	hairy pinweed
Lespedeza	lespedeza
hirta	hairy lespedeza
procumbens	trailing lespedeza
repens	creeping lespedeza
striata	common lespedeza
violacea	violet lespedeza
virginica	slender lespedeza
lespedeza	*Lespedeza*
common	*L. striata*
creeping	*L. repens*
hairy	*L. hirta*
slender	*L. virginica*
trailing	*L. procumbens*
violet	*L. violacea*
lettuce	*Lactuca* spp.
Liatris	gayfeather
cylindracea	Ontario gayfeather
pycnostachya	Kansas gayfeather
Linum virginianum	woodland flax
Liquidambar styraciflua	sweetgum
Lobelia	lobelia
appendiculata	earflower lobelia
puberula	downy lobelia
lobelia	*Lobelia*
downy	*L. puberula*
earflower	*L. appendiculata*
Lonicera	honeysuckle
japonica	Japanese honeysuckle
sempervirens	trumpet honeysuckle
lovegrass, purple	*Eragrostis spectabilis*
Ludwigia	seedbox; false loosestrife
alternifolia	bushy seedbox
decurrens	winged waterprimrose
glandulosa	creeping seedbox
Magnolia	magnolia
grandiflora	southern magnolia
virginiana	sweetbay
magnolia, southern	*Magnolia grandiflora*
Manfreda virginica	false-aloe

maple, red	*Acer rubrum*
meadowbeauty, Maryland	*Rhexia mariana*
Mecardonia acuminata	purple mecardonia
mecardonia, purple	*Mecardonia acuminata*
melic, twoflower	*Melica mutica*
Melica mutica	twoflower melic
milkpea, downy	*Galactia volubilis*
milkweed, white	*Asclepias variegata*
milkwort	*Polygala*
Mitchella repens	partridgeberry
mockstrawberry, India	*Duchesnea indica*
Monarda fistulosa	wild-bergamot beebalm
morningglory	*Ipomoea* spp.
Morus rubra	red mulberry
mountainmint	*Pycnanthemum*
slender	*P. tenuifolium*
whiteleaf	*P. albescens*
Muhlenbergia expansa	cutover muhly
muhly, cutover	*Muhlenbergia expansa*
mulberry, red	*Morus rubra*
Myrica cerifera	southern bayberry; southern waxmyrtle
needlegrass, blackseed	*Stipa avenacea*
nightshade, Carolina	*Solanum carolinense*
nutrush, littlehead	*Scleria oligantha*
Nyssa sylvatica	black tupelo; blackgum
oak	*Quercus*
black	*Q. velutina*
blackjack	*Q. marilandica*
cherrybark	*Q. falcata* var. *pagodifolia*
laurel	*Q. laurifolia*
post	*Q. stellata*
southern red	*Q. falcata*
water	*Q. nigra*
white	*Q. alba*
willow	*Q. phellos*
Ostrya virginiana	eastern hophornbeam
Oxalis	oxalis; woodsorrel
stricta	common oxalis
violacea	violet woodsorrel
oxalis, common	*Oxalis stricta*
palmetto, dwarf	*Sabal minor*
Panicum	panicum
anceps var. *rhizomatum*	spreading panicum
hians	see *Steinchisma hians*
rhizomatum	see *P. anceps* var. *rhizomatum*
scoparium	see *Dicanthelium scoparium*
virgatum	switchgrass
Panicum	
"low"	*Dichanthelium* spp.
spreading	*Panicum anceps* var. *rhizomatum*
velvet	*Dichanthelium scoparium*
Parthenocissus quinquefolia	Virginia creeper
partridgeberry	*Mitchella repens*
partridgepea, showy	*Cassia fasciculata*
Paspalum	paspalum
ciliatifolium	see *P. setaceum* var. *ciliatifolium*
circulare	see *P. laeve* var. *circulare*

dilatatum	dallisgrass
floridanum	Florida paspalum
laeve var. *circulare*	roundseed paspalum
minus	mat paspalum
notatum	bahiagrass
plicatulum	brownseed paspalum
pubescens	see *P. setaceum* var. *muhlenbergii*
setaceum var. *ciliatifolium*	fringeleaf paspalum
setaceum var. *muhlenbergii*	hurrahgrass
urvillei	vaseygrass
paspalum	*Paspalum*
brownseed	*P. plicatulum*
Florida	*P. floridanum*
fringeleaf	*P. setaceum* var. *ciliatifolium*
mat	*P. minus*
roundseed	*P. laeve* var. *circulare*
Passiflora	passionflower
incarnata	maypop passionflower
lutea	yellow passionflower
passionflower	*Passiflora*
maypop	*P. incarnata*
yellow	*P. lutea*
pencilflower	*Stylosanthes biflora*
Penstemon australis	beard-tongue
Penthorum sedoides	Virginia penthorum
penthorum, Virginia	*Penthorum sedoides*
peppervine	*Ampelopsis arborea*
persimmon, common	*Diospyros virginiana*
Phlox pilosa	downy phlox
phlox, downy	*Phlox pilosa*
Phytolacca americana	common pokeberry
pine	*Pinus*
loblolly	*P. taeda*
longleaf	*P. palustris*
shortleaf	*P. echinata*
pinkroot, woodland	*Spigelia marilandica*
Pinus	pine
echinata	shortleaf pine
palustris	longleaf pine
taeda	loblolly pine
pinweed, hairy	*Lechea villosa*
Plantago	plaintain
aristata	bottlebrush plantain
virginica	paleseed plantain
plantain	*Plantago*
bottlebrush	*P. aristata*
paleseed	*P. virginica*
plum, Mexican	*Prunus mexicana*
plumegrass, bent-awn	*Erianthus contortus*
poison-ivy	*Toxicodendron radicans*
poison-oak, eastern	*T. toxicarium*
pokeberry, common	*Phytolacca americana*
Polygala	polygala; milkwort
chapmanii	Chapman polygala
polygama	bitter polygala
polygala	*polygala*
bitter	*P. polygama*
Chapman	*P. Chapmanii*
Polypodium polypodioides	resurrection-fern

Polypremum procumbens	juniperleaf
ponyfoot	*Dichondra carolinensis*
poor-joe	*Diodia teres*
possumhaw	*Ilex decidua*
Potentilla simplex	spreading cinquefoil
Prunella vulgaris	common selfheal
Prunus	plum
mexicana	Mexican plum
serotina	black cherry
umbellata	flatwoods chokecherry
Pteridium aquilinum var. *pseudocaudatum*	southern bracken-fern
pussytoes, plantainleaf	*Antennaria plantaginifolia*
Pycnanthemum	mountainmint
albescens	whiteleaf mountainmint
tenuifolium	slender mountainmint
Pyrrhopappus carolinianus	Carolina false-dandelion
Quercus	oak
alba	white oak
falcata	southern red oak
falcata var. *pagodifolia*	cherrybark oak
laurifolia	laurel oak
marilandica	blackjack oak
nigra	water oak
phellos	willow oak
stellata	post oak
velutina	black oak
ragweed, common	*Ambrosia artemisiifolia*
rattan-vine	*Berchemia scandens*
redbud, eastern	*Cercis canadensis*
resurrection-fern	*Polypodium polypodiodes*
Rhamnus caroliniana	Carolina buckthorn
Rhexia mariana	Maryland meadowbeauty
Rhododendron nudiflorum	wild azalea
Rhus	sumac
copallina	shining sumac
radicans	see *Toxicodendron radicans*
toxicodendron	see *Toxicodendron toxicarium*
Rhynchospora	beakrush
globularis	globe beakrush
glomerata	cluster beakrush
inexpansa	nodding beakrush
rosegentian	*Sabatia*
narrowleaf	*S. brachiata*
squarestem	*S. angularis*
Rubus spp.	blackberry; dewberry
Rudbeckia	coneflower
grandiflora	rough conflower
hirta	black-eyed-susan
Ruellia pedunculata	stalked ruellia
ruellia, stalked	*Ruellia pedunculata*
rush	*Juncus*
common	*J. effusus*
needlepod	*J. scirpoides*
poverty	*J. tenuis*
roundhead	*J. validus*

Sabal minor	dwarf palmetto
Sabatia	rosegentian
angularis	squarestem rosegentian
brachiata	narrowleaf rosegentian
sage	*Salvia*
lyreleaf	*S. lyrata*
azure	*S. azurea* var. *grandiflora*
St. Andrewscross	*Ascyrum hypericoides*
St. Johnswort, Drummond	*Hypericum drummondii*
St. Peterswort	*Ascyrum stans*
Salix nigra	black willow
Salvia	sage
azurea var. *grandiflora*	azure sage
lyrata	lyreleaf sage
Sambucus canadensis	American elder
sanicle, Canada	*Sanicula canadensis*
Sanicula canadensis	Canada sanicle
sarsaparilla-vine	*Smilax pumila*
Sassafras albidum	sassafras
sassafras	*Sassafras albidum*
Schizachyrium scoparium var. *divergens*	pinehill bluestem
Schrankia uncinata	catclaw sensitivebrier
Scirpus cyperinus	woolgrass bulrush
Scleria oligantha	littlehead nutrush
Scutellaria	skullcap
elliptica	hairy skullcap
integrifolia	hyssop skullcap
sedge	*Carex*
blue	*C. complanata*
fox	*C. vulpinoidea*
thinfruit	*C. flaccosperma*
seedbox	*Ludwigia*
bushy	*L. alternifolia*
creeping	*L. glandulosa*
Selaginella spp.	selaginella
selfheal, common	*Prunella vulgaris*
sensitivebrier, catclaw	*Schrankia uncinata*
Setaria	bristlegrass
glauca	yellow bristlegrass
lutescens	see *Setaria glauca*
Seymeria cassioides	senna seymeria
seymeria, senna	*Seymeria cassioides*
silverbell, two-wing	*Halesia diptera*
Sisyrinchium spp.	blue-eyed-grass
skeltongrass	*Gymnopogon*
bearded	*G. ambiguus*
slim	*G. brevifolius*
skullcap	*Scutellaria*
hairy	*S. elliptica*
hyssop	*S. integrifolia*
Smilax	greenbrier
bona-nox	saw greenbrier
glauca	cat greenbrier
hispida	bristly greenbrier
pumila	sarsaparilla-vine
rotundifolia	common greenbrier
smallii	Small greenbrier

snakeroot, white	*Ageratina altissima*
sneezewood, purplehead	*Helenium flexuosum*
snowbell, bigleaf	*Styrax grandifolia*
Solanum carolinense	Carolina nightshade
Solidago	goldenrod
altissima	tall goldenrod
leptocephala	see *Euthamia leptocephala*
ludoviciana	Louisiana goldenrod
nitida	shiny goldenrod
odora	fragrant goldenrod
rugosa	wrinkled goldenrod
Sorghastrum nutans	yellow indiangrass
spiderwort, hairyflower	*Tradescantia hirsuticaulis*
Spigelia marilandica	woodland pinkroot
spikerush, blunt	*Eleocharis obtusa*
spurge	*Euphorbia*
flowering	*E. corollata*
spotted	*E. maculata*
stargrass, whitetube	*Aletris farinosa*
star-jasmine, climbing	*Trachelosperum difforme*
Steinchisma hians	gaping panicum
Stipa avenacea	blackseed needlegrass
Stylisma humistrata	white breweria
Stylosanthes biflora	pencilflower
Styrax grandifolia	bigleaf snowbell
sumac, shining	*Rhus copallina*
sunflower	*Helianthus*
hairy	*H. hirsutus*
swamp	*H. angustifolius*
supplejack, Alabama	*Berchemia scandens*
sweetbay	*Magnolia virginiana*
sweetgum	*Liquidambar styraciflua*
sweetleaf	*Symplocos tinctoria*
switchgrass	*Panicum virgatum*
Symplocos tinctoria	sweetleaf
Tephrosia	tephrosia
onobrychoides	weak tephrosia
virginiana	Virginia tephrosia
tephrosia	*Tephrosia*
Virginia	*T. virginiana*
weak	*T. onobrychoides*
threeawn, arrowfeather	*Aristida purpurascens*
tickclover	*Desmodium*
Dillen	*D. dillenii*
littleaf	*D. ciliare*
panicled	*D. paniculatum*
rigid	*D. rigidum*
roundleaf	*D. rotundifolium*
Toxicodendron	
radicans	poison-ivy
toxicarium	eastern poison-oak
Trachelosperum difforme	climbing star-jasmine
Tradescantia hirsuticaulis	hairyflower spiderwort
Tridens flavus	purpletop tridens
tridens, purpletop	*Tridens flavus*
trumpetcreeper	*Campsis radicans*

tupelo, black	*Nyssa sylvatica*
Ulmus alata	winged elm
Uniola	see *Chasmanthium*
uniola	*Chasmanthium*
longleaf	*C. sessiliflorum*
spike	*C. laxum*
Vaccinium	blueberry
arboreum	farkleberry
caesium	Florida blueberry
corymbosum	highbush blueberry
elliottii	Elliott blueberry
stamineum	common deerberry
virgatum	see *Vaccinium corymbosum*
vaseygrass	*Paspalum urvillei*
Verbena brasiliensis	bigbract verbena
verbena, bigbract	*Verbena brasiliensis*
Vernonia texana	Texas ironweed
Viburnum	viburnum
dentatum	arrowwood
rufidulum	rusty blackhaw
Viola spp.	violet
violet	*Viola* spp.
Vitis	grape
aestivalis	summer grape
rotundifolia	muscadine grape
waterprimrose, winged	*Ludwigia decurrens*
waxmyrtle, southern	*Myrica cerifera*
wildindigo, Nuttall	*Baptisia nuttalliana*
willow, black	*Salix nigra*
woodsorrel, violet	*Oxalis violacea*
yaupon	*Ilex vomitoria*
Yucca spp.	yucca

Thill, R. E.; Deer and cattle forage selection on Louisiana pine-hardwood sites. Res. Pap. SO-196, New Orleans, LA; U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1983, 35p.

Seasonal diet composition data and relative selectivity ratings are presented for 264 plant taxa.

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Use Valuation of Louisiana's Rural Lands: Short-Run Fiscal Impacts

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Clifford A. Hickman and Peter D. Gayer

SUMMARY

[illegible] constitution in 1974, they authorized [illegible] 1976 and became effective in [illegible] fiscal impacts of switching [illegible] use assessment. [illegible] transitional period from 1977, [illegible] market valuation [illegible] the first year use valuation was [illegible] analysis shows [illegible] the program produced first- [illegible] Initial [illegible] $0.12, or 25 percent, for forest land; $0.21, [illegible] horticultural) land; and $0.25. [illegible] increased, local units of gov [illegible] use than under market val [illegible] a smaller proportion of the total tax burden. S [illegible] tax receipts from throughout the state were [illegible] while tax payments by ineligible and nonp [illegible] at $3.9 million. If expressed in relative terms, these s [illegible] percent, respectively, of all property tax collections. Th [illegible] attributable to rural land assessments that co [illegible] under the old market based valuation system.

Use Valuation of Louisiana's Rural Lands: Short-Run Fiscal Impacts

Clifford A. Hickman and Peter D. Gayer

INTRODUCTION

In 1974, the voters of Louisiana approved a new state constitution substituting use value for market value as the legal basis for the assessment and taxation of certain classes of rural land. Legislation establishing procedures for the implementation of this new policy was passed in 1976 and became effective in 1978. In this paper, some of the short-run fiscal impacts precipitated by this change in the valuation basis are explored. In addition to examining effects on the assessments and taxes of eligible property owners, the paper also considers impacts on ineligible taxpayers and on local units of government dependent upon the property tax as a primary source of revenue.

Origins of Use Valuation in Louisiana

Historically, rural lands in Louisiana have been largely assessed and taxed on the basis of their "actual cash value", or "the valuation at which any real or personal property is assessed for the purpose of taxation, after the assessing authorities have considered every element of value in arriving at such valuation" (Louisiana Tax Commission 1942). To clarify, administrative directives stated that the cash price received for a piece of real estate or other property freely sold in the ordinary course of business was to be considered "evidentiary only", and weighed along with other factors during the property valuation process (Louisiana Tax Commission 1942).

Despite this seemingly straight-forward legislative mandate, assessment practice in Louisiana typically left much to be desired. There were two main reasons. First, parish assessors received little guidance, other than the definition and clarifying statement already mentioned, on how to estimate actual cash values. Individual discretion governed the selection and weighting of value determinants beyond sales price. Secondly, there was no specified assessment ratio. Local assessors based their assessments on whatever percentage of actual cash value they chose. Under these circumstances, there was no guarantee that similar properties, whether in the same or different taxing jurisdictions, would be assigned similar values.

A step towards greater assessment uniformity was taken when a system of land use classification was introduced. Regarding rural lands, key features of this system were as follows (Louisiana Tax Commission 1956):

- Forest lands were classified into four categories based primarily on the type of timber which they supported. These categories were Tidewater Cypress Land, Hardwood Land, Longleaf Pine Land and Other Pine Land.
- Agricultural lands were classified into three categories based primarily on their productivity. These categories were Class A, Class B and Class C.
- Marsh lands were classified into two categories on the basis of whether they were subject to inundation by salt water at high tide. These categories were Sea Marsh and Fresh Water Marsh. Each category was further subdivided into Classes A and B on the basis of whether the area in question was suitable for either reclamation or grazing.

Any rural acreage not falling into one of the preceding categories was classified either as Pasture Land—i.e. areas, other than woodland or marsh, used for grazing livestock or suitable for such use; Trap-

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ping Land—i.e. areas supporting wild fur bearing animals and used primarily for trapping purposes; and Miscellaneous Land—i.e. undeveloped areas not permitting more specific categorization.

While classification encouraged greater assessment uniformity within given land use classes and taxing jurisdictions, it did little to promote such uniformity across different jurisdictions. This situation prompted initiation of a legal action against the State of Louisiana in 1969. During the litigation, evidence showed that average assessments ranged from a low of 7 percent of market value in Lafayette Parish to a high of 35 percent in Caddo Parish (St. Clergy 1976). The plaintiff argued that such variability in average assessment ratios was discriminatory in at least three respects (St. Clergy 1976). First, it meant that property owners in parishes with high ratios were paying more property taxes to the state than they should, while property owners in parishes with low ratios were paying less.[1] Secondly, it meant that parishes with high ratios were receiving fewer state funds for the support of education than they should, while parishes with low ratios were receiving more. Finally, it meant that state reimbursements for revenue losses attributable to the homestead exemption were smaller than they should be for parishes with high ratios, and larger than warranted for parishes with low ratios. The Court found each of these arguments convincing and ruled that henceforth all property in the state was to be placed on the tax rolls at 100 percent of fair market value (St. Clergy 1976). At the request of the Governor, however, the deadline for compliance with this decision was delayed long enough to allow the Legislature to complete deliberations, already in progress, aimed at developing a proposed new state constitution. The Court was assured that an equitable system of assessment would be included in this document.

The new constitution was finally approved by the voters in 1974. Key provisions pertaining to the property tax are contained in Sections 18(A), 18(B) and 18(C) of Article VII. As amended, these sections provide as follows:

- That all property subject to ad valorem taxation—except for bona fide agricultural, horticultural, marsh and timber lands—is to be placed into one of five classes and assessed at a uniform percentage of fair market value.[2]
- That bona fide agricultural, horticultural, marsh and timber lands are to be assessed at 10 percent of their use value as opposed to their fair market value.[3]

Legislation establishing specific procedures for the implementation of these provisions was not passed until 1976 and did not become effective until 1978.

Provisions of Louisiana's Use Value Law

In reviewing the provisions of Louisiana's use value law, the following points will be considered: (1) conditions of eligibility, (2) application requirements, and (3) prescribed procedures for determining use values.

Conditions of Eligibility—As already noted, use valuation is only applicable to "bona fide" agricultural, horticultural, marsh and timber lands. In this regard, bona fide agricultural land consists of areas devoted to the commercial production of plants, animals, or their products. Tracts owned by individuals who have contracted with a federal or state agency to limit their use for agricultural production are also eligible. Bona fide horticultural land consists of areas devoted to the commercial production of fruits, vegetables, flowers or ornamental plants. Again, tracts owned by individuals who have contracted with a federal or state agency, in this case to limit their output of horticultural products, are eligible. Bona fide timber land consists of areas devoted to the commercial production of sawlogs, pulpwood or other timber products.[4] As in the previous two cases, tracts on which production has been curtailed because of a contract with a federal or state agency are eligible. Finally, bona fide marsh land consists of wetland areas other than those used for the commercial production of agricultural, horticultural or timber products (Title 47, Section 2302, Louisiana Revised Statutes).

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[1] At the time of the lawsuit, the state levied and ad valorem tax of 5.75 mills on property. This tax was dropped in 1973.

[2] The five classes of property and the assessment ratios applicable to each are as follows: (1) land—10 percent; (2) improvements for residential use—10 percent; (3) electric cooperative properties, excluding land—15 percent; (4) public service properties, excluding land—25 percent; and (5) other property—15 percent.

[3] Fair market value is defined to mean . . . "the price for property which would be agreed upon between a willing and informed buyer and a willing and informed seller under usual and ordinary circumstances; the highest price estimated in terms of money which property will bring if exposed for sale on the open market with reasonable time allowed to find a purchaser who is buying with knowledge of all the uses and purposes to which the property is best adapted and for which it can be legally used." (Title 47, Section 2321, Louisiana Revised Statutes).

[4] Land does not actually have to be stocked with trees in order to qualify as a bona fide timber property. Bare land will qualify if it supported tree growth within the last 3 years and is not currently being used for nonforest purposes.

Besides the foregoing use restrictions, agricultural, horticultural and timber lands must satisfy at least one of two additional conditions in order to qualify for use assessment. They must be 3 or more acres or, alternatively, they must have produced an average annual gross income of $2,000 or more during the last 4 years (Title 47, Section 2303, Louisiana Revised Statutes).

Once established, eligibility can be lost in either of two ways. First, the character of the property itself may be changed so that the legislative requirements for continued participation are no longer met. In this instance, landowners must notify the parish assessor within 60 days of the date when eligibility is lost. Thereafter their properties are assessed and taxed on the basis of fair market value. Secondly, the property may be sold for a price four or more times greater than its estimated use value. In this instance, the purchaser is given 60 days to demonstrate either that the sales price included something of value aside from the land itself (e.g. standing crops, timber, improvements) or that the property remains eligible on the basis of use and all other conditions. Upon such demonstration, use valuation is continued (Title 47, Section 2305, Louisiana Revised Statutes).

Application Requirements.—While the language of the 1974 Constitution suggests that use assessment shall be applied to all eligible lands, the implementing legislation passed in 1976 requires qualified owners to apply for such treatment every 4 years. Application is to be made to the assessor of the parish where the property is located. In addition to the application itself, an agreement must be signed stating that the property will continue to be devoted to one or more of the qualifying uses. Any individual who receives use valuation by virtue of fraudulent information supplied during the application process is penalized. This penalty equals, for each year by which such treatment is so received, five times the difference between the amount of tax paid with use assessment and the amount that would have been paid with market assessment (Title 47, Sections 2304 and 2306, Louisiana Revised Statutes).

Use Valuation Procedures.—For bona fide agricultural, horticultural and timber lands, use value is defined to mean "the highest value of such land when used by a prudent agricultural, horticultural or timber operator for the sole purpose of continuing the operation as a commercial agricultural, horticultural or timber use" (Title 47, Section 2301, Louisiana Revised Statutes). For bona fide marsh lands, use value is defined as "the highest value of such land for the sole purpose of continuing the traditional use of the marsh lands for hunting, fishing, trapping or various types of aquaculture by a prudent manager of marsh lands" (Title 47, Section 2301, Louisiana Revised Statutes). Both definitions make it apparent that neither fair market value nor value to the general public are to be considered in assessing qualifying properties.

In the case of bona fide agricultural, horticultural and timber lands, primary responsibility for determining use value is assigned to the Louisiana Tax Commission. While exact procedures vary by land type, in each instance an income capitalization approach is employed. This approach encompasses the following basic steps:

1. Annual product yields are estimated for lands of differing productivities. In this regard, four productivity classes are recognized for each type of land. These are designated Class I, Class II, Class III and Class IV. For agricultural and horticultural properties, the classes are based upon a system formulated by the U.S. Soil Conservation Service. For timber properties, they are based upon a scheme developed by the U.S. Forest Service.

2. Current product prices are monitored and then multiplied by the anticipated product yields thus providing an estimate of annual gross revenue.

3. Data on the annual management costs that would be incurred by a prudent agricultural, horticultural or timber land operator are compiled and subsequently deducted from annual gross revenue to determine annual net revenue.

4. Use value is calculated by dividing annual net income by an appropriate capitalization rate. The latter is to be selected after weighing several variables; however, for agricultural and horticultural properties it cannot be less than 12 percent, and for timber properties it must be at least 10 percent (Title 47, Section 2307, Louisiana Revised Statutes).

In the case of bona fide marsh lands, the individual parish assessors have the primary responsibility for establishing use value. In fulfilling this assignment they are required to consider the income obtainable from the traditional uses of marsh lands, any physical and economic risks, prevailing interest rates, the liquidity of such investments, and any federal or state regulatory constraints which impinge upon the use of wetlands. Only two classes of marsh land are recognized during the valuation process; these are Salt Water Marsh and Fresh Water Marsh.

Controversial Aspects of Use Valuation

Louisiana, like most states having similar legislation, enacted its use value law primarily to prevent the premature or forced conversion of forest, farm and other rural lands to more intensive uses. The experiences of other states had shown, under a system of market based assessments, such losses could be substantial—particularly around areas subject to pressures from urbanization, industrialization, second home construction, or recreational development. In these settings, rural land market values can easily exceed values based upon current income producing capability. When reflected in market based assessments, these higher land values increase the tax burden on rural property owners even though their current ability-to-pay is not enhanced. If the resultant "profit-squeeze" becomes sufficiently severe, the affected lands can be forced into development. Use valuation, by restoring the relationship between a property's taxable value and its income-producing potential, offers a means of addressing this problem. Proponents argue it enables property owners to profitably keep their undeveloped lands in traditional uses. Several important social benefits result. These include: (1) greater assurance of sufficient food and fiber to meet future needs; (2) the economic activity generated by viable agricultural and forest industries; (3) increased outdoor recreation opportunities for urban and suburban residents; and (4) protection, or perhaps even improvement, of air and water quality.

At present, most states authorize use assessment for certain classes of rural land. However, in spite of this popularity, such legislation has become increasingly controversial. Three main areas of controversy have developed. One area concerns the effectiveness of use valuation as a means of discouraging development. Critics contend that without rural zoning or other land use controls, use assessment will have little impact on landowner development decisions. Arguments used to support this position are: (1) that the cost savings provided by use assessment are small compared to the major cost of withholding land from development—namely, foregone interest; (2) that many property owners will be unable to resist the potentially large capital gains realizable through land sales and development; (3) that use valuation addresses only one of a broad range of economic, demographic, sociological and transitional factors which can enter into the decision to sell or develop a property; and (4) that the tax subsidy represented by use assessment will be capitalized into higher land values and thus influence the development decisions of the initial property owners only (Atkinson 1977, Coughlin et. al. 1978, Gloudemans 1974, Keene et. al. 1976, Malone and Ayesh 1979).

A second controversy concerns the possible effects of use valuation on ineligible property owners. Critics contend that the tax burden on these individuals is almost sure to increase, and that because use assessment is unlikely to provide the intended public benefits, this redistribution of the tax load will probably be unwarranted. This conclusion is based upon the belief that use valuation will normally cause the value of the assessment base to decline and that local governments, in an effort to maintain revenue stability, will typically respond by increasing tax rates. For participants, the impact of a higher rate is partially offset by a reduced assessment. For nonparticipants, however, this is not the case. Given constant assessments and an increased rate, each nonparticipant's tax bill rises, and collectively they bear a greater proportion of the total tax burden. This phenomenon is called "tax-shifting" (Coughlin et. al. 1978, Dunford 1980, Keene et. al. 1976).

The last area of controversy concerns the possible effects of use valuation on the amount of tax revenue accruing to local units of government. Critics contend that the government's ability to increase tax rates is often constrained by political pressures or legislative ceilings, and that consequently local tax revenues, and ultimately the public services which they support, may be reduced by initiating use assessment. This occurs because erosion in the value of the tax base cannot be readily offset by adjustments in the tax rate (Keene et. al. 1976).

Study Objectives

In this study, the short-run fiscal impacts precipitated by the adoption of use valuation in Louisiana were explored. Here the qualifying phrase "short-run" refers to the transitional period from 1977 (i.e. the last year in which all rural lands were assessed and taxed on the basis of fair market value) to 1978 (i.e. the first year in which rural lands were eligible for use valuation).[5] Within this context, the specific objectives of the study were:

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[5] Some states with use value statutes require local assessors to keep two sets of assessment records—one based on use values and the other on market values. In Louisiana, however, this is not the case; only use value assessments are carried forward from year-to-year. For this reason, no attempt was made to examine the fiscal impacts of use valuation for the most recent tax year. Without readily available information as to the current market values of enrolled properties, current assessment and tax changes attributable to use valuation would have been very difficult to estimate.

1. To estimate—by parish and for the state as a whole—the extent to which use valuation was adopted by the owners of agricultural, horticultural, marsh and timber lands.
2. To estimate—by parish and for the state as a whole—how use valuation affected average per acre assessments and taxes on participating agricultural, horticultural, marsh and timber lands.
3. To estimate—by parish and for the state as a whole—how total annual property tax revenues were impacted by the use valuation of agricultural, horticultural, marsh and timber lands.
4. To estimate—by parish and for the state as a whole—the redistributional (i.e. tax-shifting) effects of extending use valuation to agricultural, horticultural, marsh and timber lands.

As these objectives suggest, in this study attention was focused on the last two of the three previously mentioned areas of controversy. Questions pertaining to the effectiveness of Louisiana's use value law as a policy tool for discouraging premature or forced development were not considered.

METHODOLOGY

Study procedures may be reviewed in two stages: Data sources utilized, and analytical procedures employed.

Data Sources

All data were obtained from the Eighteenth and Nineteenth Biennial Reports of the Louisiana Tax Commission. These reports contain statistics about the property tax; the Eighteenth for the years 1976 and 1977, and the Nineteenth for the years 1978 and 1979.

For 1977, the information collected, by parish, included: (1) the total acreage in each class of eligible land; and (2) the total market value assessment associated with each class of eligible land. For 1978, the following parish data were gathered: (1) the total acreage in each class of eligible land; (2) the total acreage of "miscellaneous" agricultural and timber land; (3) the total use value assessment associated with each class of eligible land; (4) the total assessed value of all taxable property; (5) the total amount of tax revenues raised; and (6) the average millage rate. Average millage rates were not obtained directly, but were calculated by dividing the total amount of taxes raised by the total assessed value of all taxable property.

Regarding the collected data, two points warrant further comment. First, no acreage or assessment figures were obtained for horticultural lands because the Tax Commission, in its Biennial Reports, lumps such lands together with agricultural properties. Secondly, certain difficulties were encountered in using the data from the two reports. The most common problem was that one report would show a particular parish as having a certain type of rural land whereas the other would not. In these cases, no attempt was made to estimate the fiscal effects of implementing use valuation—either for the type of land in question or for all enrolled lands combined. A less frequent problem was that some 1978 use value assessment figures were extremely high. While such assessments were undoubtedly a consequence of assessor unfamiliarity with the new valuation system, they were nonetheless used in the analysis because they were, in fact, the taxable values employed in 1978.

Data Analysis

Analytical procedures will be discussed by objective and illustrated by example. While any parish and type of eligible land, including all types combined, could be used for this purpose, the case of timber land in Avoyelles Parish will be considered. Before beginning the review, the required data must be set forth.

For the tax year 1977, the following data would be obtained from the Tax Commission's Eighteenth Biennial Report:

1. Total acreage in each class of timber land.

Class	Total Acreage (acres)
Hardwood Land	225,008
Longleaf Pine Land	- -
Other Pine Land	13,547
Tidewater Cypress Land	- -

2. Total market value assessment associated with each class of timber land.

Class	Total Assessment (dollars)
Hardwood Land	1,349,510
Longleaf Pine Land	- -
Other Pine Land	81,080
Tidewater Cypress Land	- -

For the tax year 1978, the Tax Commission's Nineteenth Biennial Report would be used to obtain the information listed below:

1. Total acreage in each class of timber land.

Class	Total Acreage (acres)
Class I	16,516
Class II	40,526
Class III	113,014
Class IV	7,665

2. Total acreage of "miscellaneous" timberland.[6]
   19,266 acres

3. Total use value assessment associated with each class of timber land.

Class	Total Assessment (dollars)
Class I	196,040
Class II	408,370
Class III	740,530
Class IV	39,040

4. Total assessed value of all taxable property.
   $51,751,630
5. Total amount of tax revenues raised.
   $2,387,487
6. Average millage rate.[7]
   46.13 mills

Objective (1): Estimating Extent of Adoption.—Election of use valuation by qualified property owners was measured in two ways: the acreage of land enrolled, and the acreage enrolled as a percentage of the acreage eligible for enrollment. For each parish and type of eligible land, the acreage enrolled was determined, using the 1978 data, by summing the acreage reported for each productivity class. For timber land in Avoyelles Parish, the computation was as follows:

acreage enrolled
= acres of Class I timber land +...+ acres of Class IV timber land
= 16,516 acres + 40,526 acres + 113,014 acres +7,665 acres
= 177,721 acres.

To express participation on a percentage basis, it was first necessary to estimate the amount of each type of land eligible for enrollment. This was done by adding, to the acreage enrolled, the acreage classified as "miscellaneous". Since the latter indicates the amount of land not being assessed on the basis of use, the sum of the two figures approximates the total area eligible for use valuation. Given this approximation, the desired participation percentages can be readily calculated by dividing the acreage enrolled by the acreage eligible and multiplying the quotient by 100. For timber land in Avoyelles Parish, the computation would be as follows:

participation percentage
= 100 [acreage of timber land enrolled ÷ (acreage of timber land enrolled + acreage of miscellaneous timber land)]
= 100 [177,721 acres ÷ (177,721 acres + 19,266 acres])
= 90.2 percent.

The preceding approach to estimating the participation percentages has shortcomings. For one thing, it fails to recognize that for any qualifying land use, some properties of insufficient size or income will be ineligible. For another thing, since the Tax Commission's Biennial Reports did not list any "miscellaneous" marsh land, it had to be assumed, perhaps unrealistically, that all privately owned marsh was assessed on the basis of use. Finally, for agricultural and timber lands, it is doubtful that the reported "miscellaneous" acreage figures consistently reflect all the additional areas eligible for use valuation. Some assessors apparently designate rural lands not being assessed on the basis of use as "miscellaneous land" without making any attempt to show the actual land use.[8]

Objective (2): Estimating Effects on Participants.—The effects of use valuation on the average per acre assessments and taxes of participating property owners were estimated in three steps: (1) market value assessments and taxes were derived for the tax year 1978, (2) use value assessments and taxes were derived for the same tax year, and (3) the two sets of figures were compared.

Regarding step (1), for each parish and type of eligible land, average per acre market value assessments were determined, using the 1977 data, by aggregating the total assessed valuations and total acreages associated with all recognized land classes and then dividing the first sum by the second. For timber land in Avoyelles Parish, the calculation should be:

average per acre market value assessment
= (total assessed valuation of Hardwood Land

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[6] Represents those forest properties which continue to be assessed on the basis of market value.

[7] Represents the dollars of tax per thousand dollars of assessed valuation.

[8] A parish-by-parish comparison of the total acreage of privately owned timber land as determined by: (1) the procedure used in this study, and (2) the use of Forest Survey statistics—revealed that the first method often results in a smaller acreage figure than the second.

+...+ total assessed valuation of Tidewater Cypress Land) ÷ (acreage of Hardwood Land +...+acreage of Tidewater Cypress Land)
= ($1,349,510 + 0 + $81,080 + 0) ÷ (225,088 acres + 0 + 13,547 acres + 0)
= $5.99/acre.

The corresponding market value taxes were obtained by multiplying the preceding assessments by 1978 millage rates. For timber land in Avoyelles Parish, this process yields the following result:

average per acre market value tax
= average per acre market value assessment of timber land × average millage rate
= $5.99/acre × 46.13 mills
= $.28/acre.

Turning to step (2), average per acre use value assessments and taxes were determined in the same manner as their market value counterparts; the only difference being that the total assessed valuation and acreage data for 1978 were utilized. Referring again to the case of timber land in Avoyelles Parish, we have the following:

average per acre use value assessment
= (total assessed valuation of Class I timber land +...+ total assessed valuation of Class IV timber land) ÷ (acreage of Class I timber land +...+ acreage of Class IV timber land)
= ($196,040 + $408,370 + $740,530 + $39,040) ÷ (16,516 acres + 40,526 acres + 113,014 acres + 7,665 acres)
= $7.79/acre.

average per acre use value tax
= average per acre use value assessment of timber land × average millage rate
= $7.79/acre × 46.13 mills
= $.36/acre.

Finally, concerning step (3), the effects of use valuation on average per acre assessments and taxes were calculated by subtracting the previous market value figures from the corresponding use values. This process is shown below for the case of timber land in Avoyelles Parish:

effect on average per acre assessment
= average per acre use value assessment of timber land — average per acre market value assessment of timber land
= $7.79/acre — $5.99/acre
= + $1.80/acre.

effect on average per acre tax
= average per acre use value tax on timber land — average per acre market value tax on timber land
= $.36/acre — $.28/acre
= + $.08/acre.

The three-step procedure outlined above rests upon the assumption that the 1977 market values of all enrolled lands can be carried over, without adjustment, to 1978. While this premise is almost certainly untrue, it was believed to be acceptable since the time interval involved was only one year. Other options would have been to assume some average annual rate of value change for each type of qualifying land or, alternatively, to take a sample of actual 1978 market values. Both of these latter approaches were judged to be impractical.

Objective (3): Estimating Impacts on Tax Revenues.—The impacts of use valuation on the amount of tax revenue accruing to local units of government were estimated by deducting, from the total revenues collected in 1978 from each type of enrolled land, the total revenues that would have been collected if these same lands had been assessed and taxed on the basis of market value.

For each parish and type of eligible land, the total amount of revenue collected in 1978 was determined by multiplying the average per acre use value tax by the total number of acres being assessed on the basis of use value. For timberland in Avoyelles Parish, the computation is as follows:

total revenues collected given use valuation
= average per acre use value tax on timber land × acreage of timber land enrolled
= $.36/acre × 177,721 acres
= $63,802.

The amount of revenue that would have been collected in 1978 if each type of eligible land had been assessed and taxed on the basis of market value was calculated by multiplying the average per acre market value tax by the total acreage enrolled. The computation is shown below for timber land in Avoyelles Parish:

total revenues collectible given market valuation
= average per acre market value tax on timber land × acreage of timber land enrolled.
= $.28/acre × 177,721 acres
= $49,051.

The desired revenue impact estimate was determined, as indicated earlier, by subtracting the revenues collectible given market valuation from the revenues actually collected given use valuation. For the case example, this calculation yields the following result:

impact on total tax revenues

= total revenue collected from timber land given use valuation — total revenue collectible from timber land given market valuation

= $63,802 — $49,051

= + $14,751.

Objective (4): Estimating the Redistributional Consequences.—The tax-shifting effects of adopting use valuation were analyzed by assuming that local units of government would respond to changes in the assessed value of the tax base by altering tax rates to maintain revenue stability. Given this premise, three measures of the tax-shift were developed. Each indicator is discussed below.

The first measure was the change in the tax rate required to keep revenues constant. For each parish and type of eligible land, several steps were needed to quantify this variable. To start, the total use assessment of enrolled land was deducted from the total assessed value of all taxable property to obtain a residual representing the total assessed value of all taxable property exclusive of the type of land under consideration. For timber land in Avoyelles Parish, the computation would be as follows:

total assessed value of all taxable property exclusive of participating timber land

= total assessed valuation of all taxable property — (total assessed valuation of Class I timber land +...+ total assessed valuation of Class IV timber land)

= $51,751,630 — ($196,040 + $408,370 + $740,530 + $39,040)

= $50,367,650.

Next, the total acreage of each type of land, being assessed on the basis of use was multiplied by the corresponding average per acre fair market value assessment, to obtain a product approximating the total fair market value assessment of the type of land under consideration. This product was then added to the residual assessment figure computed in the preceding step, thereby yielding the total assessed value of all taxable property when enrolled lands are subject to market instead of use valuation. For the selected case example, the procedure would be as indicated below:

total assessed value of all taxable property given market valuation of participating timber land

= total assessed value of all taxable property exclusive of timber land + (total acreage of timber land enrolled × average per acre market value assessment of timber land)

= $50,367,650 + (177,721 acres × $5.99/acre)

= $51,432,199.

Finally, the desired estimate of the change in the tax rate required to maintain revenue stability was derived by subtracting, from the average 1978 millage rate, the millage rate obtained by dividing the amount of tax revenue actually raised in 1978 by the total assessment figure generated in the preceding step. For timber land in Avoyelles Parish, the result would be as shown below:

change in tax rate required to maintain revenue stability

= average millage rate given use valuation of timber land — (total tax revenue to be raised ÷ total assessed value of all taxable property given market valuation of timber land)

= 46.13 mills — $2,387,487 ÷ $51,432,199)

= 46.13 mills — 46.42 mills

= — 0.29 mills.

The second tax-shifting measure was the total dollar amount of taxes shifted. For each parish and type of qualifying land, two steps were required to quantify this variable. Holding total tax revenues constant at 1978 levels, the first step was to determine how much tax would be collected from enrolled lands if they were assessed at market value. This figure was derived by multiplying the total acreage of land enrolled by the average per acre market value assessment of such land and the millage rate required to insure revenue stability when all property is subject to market valuation. The second step was to deduct from the preceding revenue figure, the total amount of tax actually collected from the enrolled lands in 1978. The latter was previously calculated by multiplying the total acreage of land enrolled by the average per acre use value tax. For timber land in Avoyelles parish, the computations would be made as follows:

tax revenue collected from participating timber land given market valuation

= total acreage of timber land enrolled × average per acre market value assessment of timber land × adjusted millage rate

= 177,721 acres × $5.99/acre × 46.42 mills

= $49,286.

total dollar amount of taxes shifted to the owners of nonparticipating property

= tax revenue collected from timber land given market valuation — tax revenues collected from timber land given use valuation

= $49,286 — $63,802

= — $14,516.

The last tax-shifting measure was the percentage of the total tax burden shifted. Since the amounts of tax revenue that would be obtained from enrolled lands, in both the market value and use value cases, have already been determined; this variable is easily quantified by: (1) expressing each of the preceding revenue figures as percentages of the total revenues raised, and (2) deducting the second percentage from the first. The computations, for timber land in Avoyelles parish, are outlined below:

percentage of tax burden borne by participating timber land given market valuation
= 100 (tax revenue collected from timber land given market valuation ÷ total tax revenues raised)
= 100 ($49,286 ÷ $2,387,487)
= 2.07 percent.

percentage of tax burden borne by participating timber land given use valuation
= 100 (tax revenue collected from timber land given use valuation ÷ total tax revenues raised)
= 100 ($63,802 ÷ $2,387,487)
= 2.67 percent.

percentage of total tax burden shifted to the owners of nonparticipating property
= percentage of tax burden borne by timber land given market valuation — percentage of tax burden borne by timber land given use valuation
= 2.07 percent — 2.67 percent
= — 0.60 percent.

RESULTS

Given the extensive data developed, the following restrictions were observed in preparing this section of the paper:

- Where different types of qualifying land are recognized—i.e. forest, agricultural (including horticultural), marsh, and the total of all types combined—enrollment and fiscal impact statistics are presented on a statewide basis only.
- Where different parishes are recognized, enrollment and fiscal impact statistics are provided for only one type of qualifying land—i.e. the sum of all types combined.

All findings not explicitly reported in the body of the paper are available through a series of nine appendix tables.

Extent of Adoption

Table 1.—*Extent of adoption of use valuation in Louisiana, 1978*

Type of land	Amount of land assessed at use value	Proportion of all eligible land assessed at use value
	acres	*percent*
Forest	11,888,288	98.3
Agricultural[1]	7,496,891	97.2
Marsh	4,074,919	100.0
Total	23,460,098	98.2

[1] Includes horticultural land.

In the first year, enrollments under Louisiana's use value law were extremely high. As indicated in table 1, close to 23.5 million acres of rural land were assessed on the basis of use in 1978. This total included approximately 12 million acres of forest land, 7.5 million acres of agricultural land, and 4 million acres of marsh. Expressing these figures as percentages of the total amounts of each type of land eligible for use valuation shows that, for the state-as-a-whole, an estimated 98.2 percent of all qualifying lands were enrolled. The level of adoption was greatest for marsh land, a full 100 percent, and lowest for agricultural land, only 97.2 percent. For forest land, the participation percentage was 98.3.

Enrollment levels within the individual parishes have been depicted in figure 1. Two parishes, East Baton Rouge and Orleans, both heavily urbanized, contained no qualifying rural lands. Of the remaining parishes, all eligible properties were being assessed on the basis of use in 39, between 90 and 100 percent in 20, and between 80 and 90 percent in 2. Only one parish, Beauregard, had an adoption level of less than 80 percent. In this instance, only 75.3 percent of all eligible lands were being assessed on the basis of use.

Effects on Participating Properties

Although exceptions occurred, implementation of use valuation generally caused assessments and taxes on participating properties to increase. In absolute terms, the magnitude of the increases tended to be small; in percentage terms, however, they were sometimes large.

Table 2 indicates that under market valuation forest lands would have a taxable value of $7.21/acre, agricultural lands a value of $21.98/acre, and marsh lands a value of $3.74/acre. For all three land types combined, the average market assessment would be $11.33/acre. As use valuation is implemented, these averages rise. The new taxable values become $8.97/acre for forest land, an increase of $1.76; $25.30/acre for agricultural land, an increase of $3.32; $7.61/acre for marsh, an increase of $3.87;

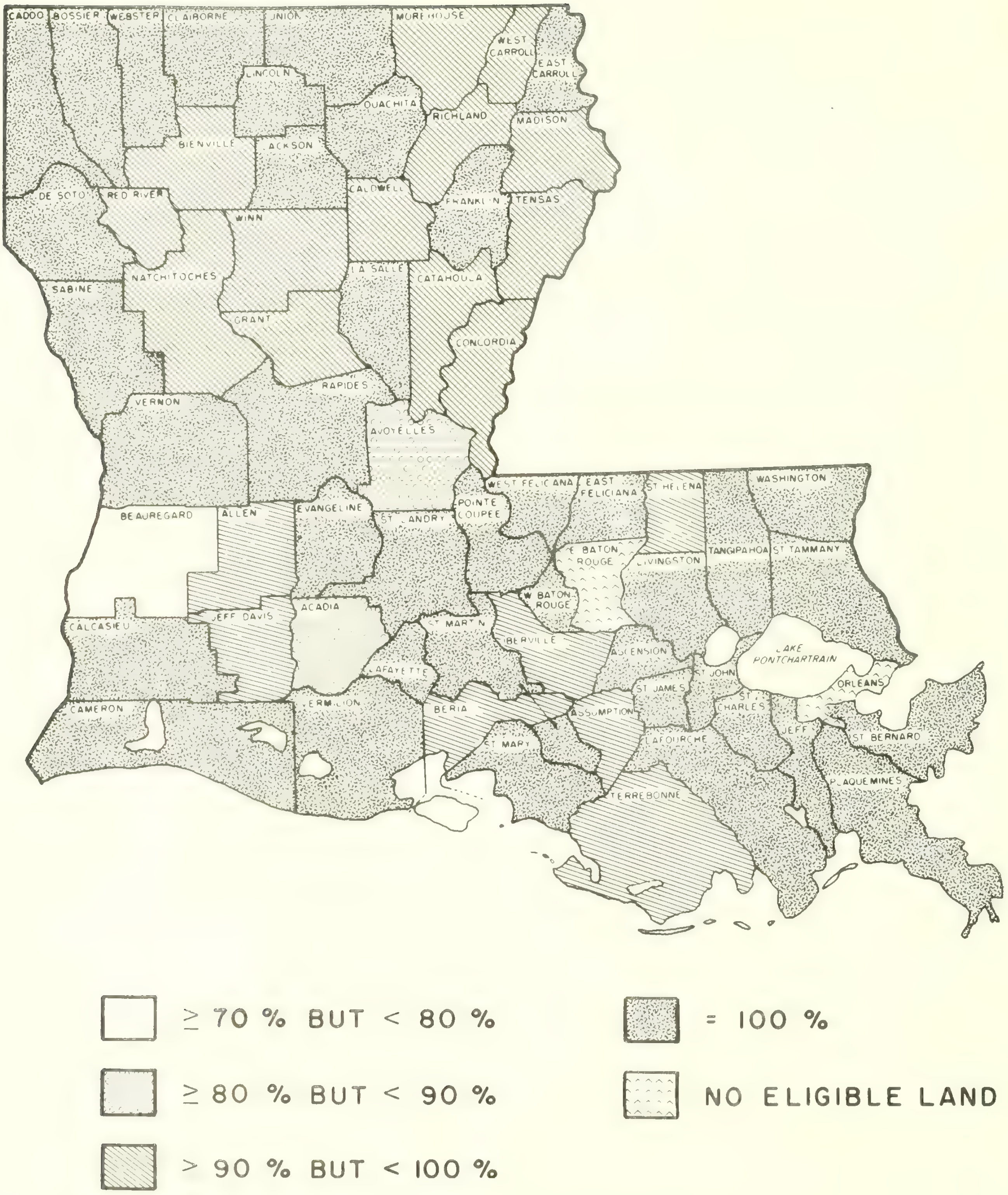


Figure 1.—*Proportion of all eligible land assessed at use value in Louisiana parishes, 1978.*

Table 2.—*Analysis of the effects of use valuation on average per acre assessments in Louisiana, 1977 to 1978*

Type of land	Average fair market value assessment	Average use value assessment	Change average assessment due to use valuation
	$/acre		
Forest	7.21	8.97	+1.76
Agricultural[1]	21.98	25.30	+3.32
Marsh	3.74	7.61	+3.87
Total	11.33	13.95	+2.62

[1]Includes horticultural land.

and $13.95/acre for all lands combined, an increase of $2.62. In interpreting these figures, it should be remembered that the assessment ratio applicable to all land in Louisiana is 10 percent.

Figure 2 illustrates how use valuation affected average per acre assessments within individual parishes. Of the 36 cases where the effects were quantifiable, 26 parishes experienced assessment increases of less than $5.00/acre, 4 experienced increases of between $5.00 and $10.00/acre, and 2 experienced increases of over $10.00/acre. Assessment declines were encountered in only four instances. In three of these parishes the decline was smaller than $5.00/acre; in the fourth it was greater than $5.00 but less than or equal to $10.00/acre.

Table 3 indicates that with market valuation the tax levy would be $.46/acre on forest lands, $1.42/acre on agricultural lands, $.24/acre on marsh lands, and $.73/acre on all lands combined. As use valuation is implemented, these tax levels rise. The average tax on forest land increases by $.12, to a total of $.58/acre; the average tax on agricultural land increases by $.21, to a total of $1.63/acre; the average tax on marsh increases by $.25, to a total of $.49/acre; and the average tax on all enrolled lands increases by $.17, to a total of $.90/acre. These higher taxes are predictable given the higher assessments caused by adoption of use valuation.

Figure 3 describes the tax changes within individual parishes and reveals two tendencies. First, in Louisiana use assessment typically, but not invariably, caused the average per acre tax on participating properties to rise. Among the parishes where the tax effects could be estimated, increases occurred in 32 cases and declines in only 4. Secondly, in absolute terms the tax changes, like the previous assessment changes, tended to be modest. In 33 of the 36 cases where the tax effects were estimated, the amount of the change, either increase or decrease, was less than or equal to $.50/acre.

Table 3.—*Analysis of the effects of use valuation on average per acre taxes in Louisiana, 1977 to 1978*

Type of land	Average fair market value tax	Average use value tax	Change in average tax due to use valuation
	$/acre		
Forest	0.46	0.58	+0.12
Agricultural[1]	1.42	1.63	+0.21
Marsh	0.24	0.49	+0.25
Total	0.73	0.90	+0.17

[1]Includes horticultural land.

Table 4.—*Percentage change in average per acre assessment and taxes attributable to adoption of use valuation in Louisiana, 1977 to 1978*

Type of land	Percentage change in average per acre assessments and taxes
	percent
Forest	+25.25
Agricultural[1]	+14.95
Marsh	+103.82
Total	+23.21

[1]Includes horticultural land.

The observed assessment and tax changes, while generally small in absolute terms, were sometimes large when expressed as percentages of the original assessment and tax levels. Table 4 shows that, statewide, average per acre assessments and taxes on marsh lands rose by more than 100 percent as a result of switching to use valuation. On forest

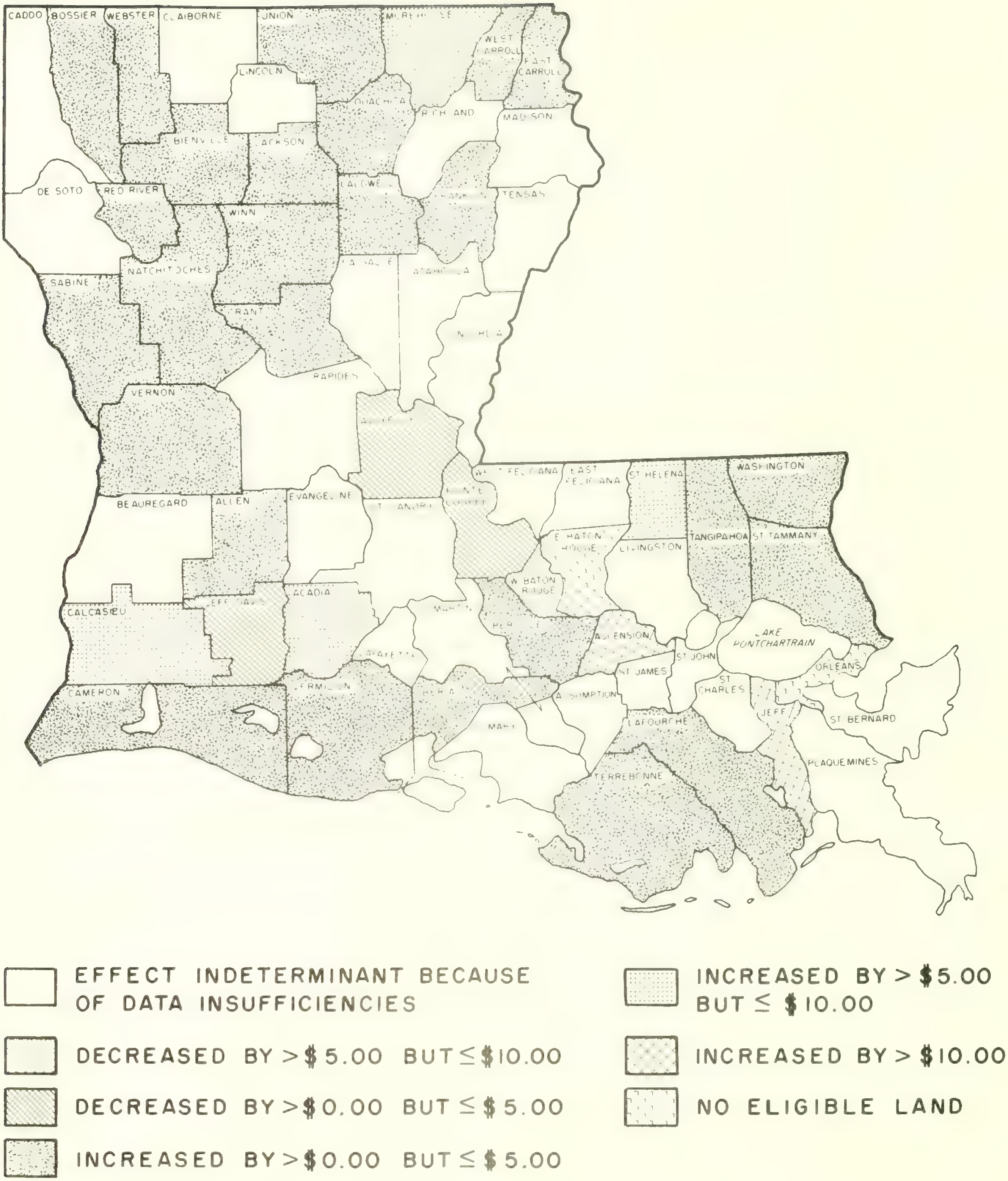


Figure 2.—*Effects of use valuation on average per acre assessments in Louisiana parishes, 1977 to 1978.*

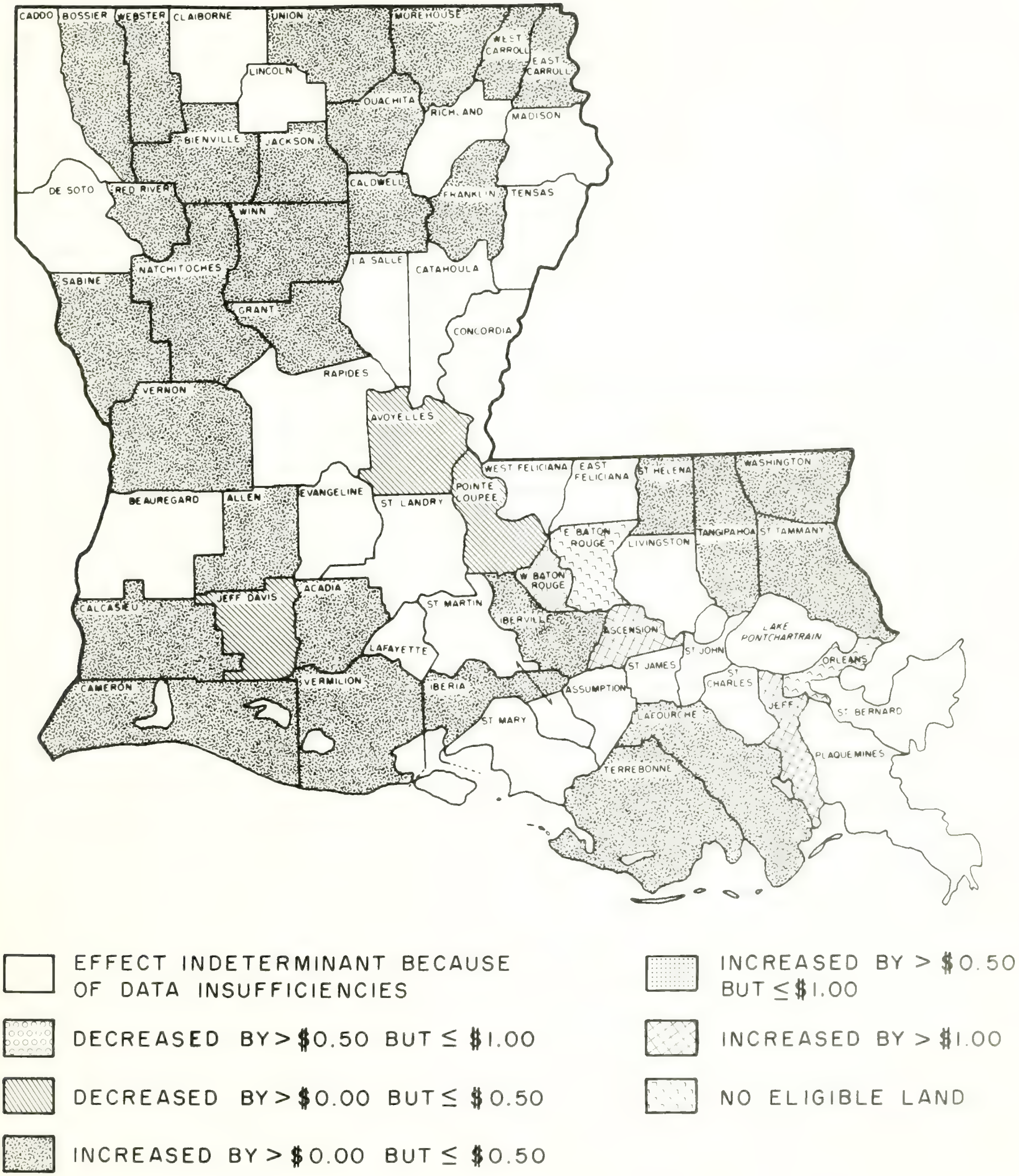


Figure 3.—*Effects of use valuation on average per acre taxes in Louisiana parishes, 1977 to 1978.*

Table 5.—*Impacts of use valuation on total property tax revenues in Louisiana, 1978*

Type of land	Total revenues collectible given market valuation	Total revenues collected given use valuation	Change in total revenues due to use valuation
	dollars		
Forest	5,516,166	6,871,430	+1,355,264
Agricultural[1]	10,615,598	12,212,435	+1,596,837
Marsh	982,055	1,996,710	+1,014,655
Total	17,113,819	21,080,575	+3,966,756

[1]Includes horticultural land.

and agricultural lands, the comparable percentage changes were approximately +25 percent and +15 percent, respectively. For all enrolled lands, the weighted average percentage increase was just over 23 percent.

Within individual parishes, the percentage changes in average per acre assessments and taxes were as presented in figure 4. Of the 32 parishes where increases occurred—in 18 cases the increase was 25 percent or less, in 6 cases it was between 25 and 50 percent, in 4 cases it was between 50 and 75 percent, in 2 cases it was between 75 and 100 percent, and in 2 cases it was over 100 percent. Of the four parishes where assessments and taxes declined, in three the decline was 25 percent or less and in one it was between 25 and 50 percent.

Impacts on Tax Revenues

Increased assessments and taxes on participating properties, as one would expect, tended to increase the revenues accruing to local units of government. In absolute terms, some increases seem large; expressed as percentages of all property tax receipts, however, they are generally rather minor.

Table 5 indicates that for the entire state, given market valuation and the average millage rates employed in 1978, approximately $5.5 million in revenues would have been collected from participating forest lands, $10.6 million from participating agricultural lands, and $1.0 million from participating marsh lands. Thus, for all enrolled lands combined, total tax receipts would have been roughly $17.1 million. With use valuation, total collections were somewhat higher. Forest lands provided about $6.9 million in revenues, a gain of over $1.3 million; agricultural lands about $12.2 million, a gain of just under $1.6 million; and marsh lands about $2.0 million, a gain of over $1.0 million. For all participating lands combined, total tax receipts thus approached $21.1 million under use assessment, an increment of nearly +4.0 million.

As shown in figure 5, the revenue impacts of use valuation were highly variable among parishes. Consistent with earlier findings, of the 36 cases where the impacts were quantifiable, tax receipts increased in 32 and declined in 4. Among parishes experiencing increases, in 15 the increase was $50,000 or less, in 5 it was between $50,000 and $100,000, in another 5 it was between $100,000 and $150,000, in 4 it was between $150,000 and $200,000, and in 3 it exceeded $200,000. Considering parishes where descreases occurred, in 2 the decline was $50,000 or less, and in 2 it exceeded $50,000 but not $100,000.

If the revenue changes attributable to use valuation are expressed as percentages of the total tax revenues collectible given market valuation of all taxable property, one obtains the figures shown in table 6. These data indicate that, despite the high levels of enrollment, in 1978 assessment of Louisiana's rural lands on the basis of use as opposed to fair market value had relatively little impact on total property tax receipts. For agricultural, forest and marsh lands, average percentage changes of

Table 6.—*Percentage change in total property tax revenues attributable to adoption of use valuation in Louisiana, 1978*

Type of land	Percentage change in total tax revenues
	percent
Forest	+0.26
Agricultural[1]	+0.31
Marsh	+0.20
Total	+0.77

[1]Includes horticultural land.

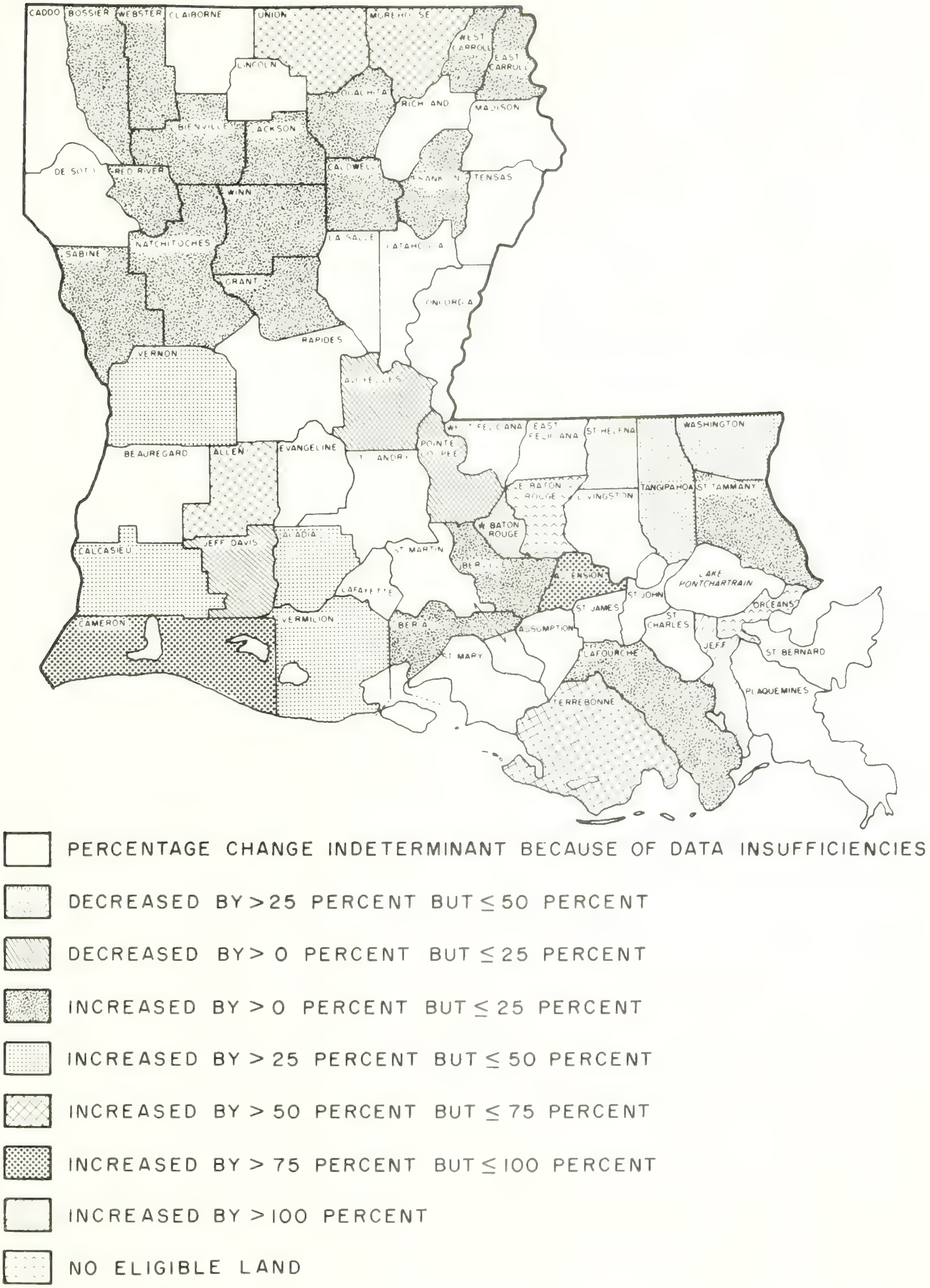


Figure 4.—*Percentage change in average per acre assessments and taxes attributable to adoption of use valuation in Louisiana parishes, 1977 to 1978.*

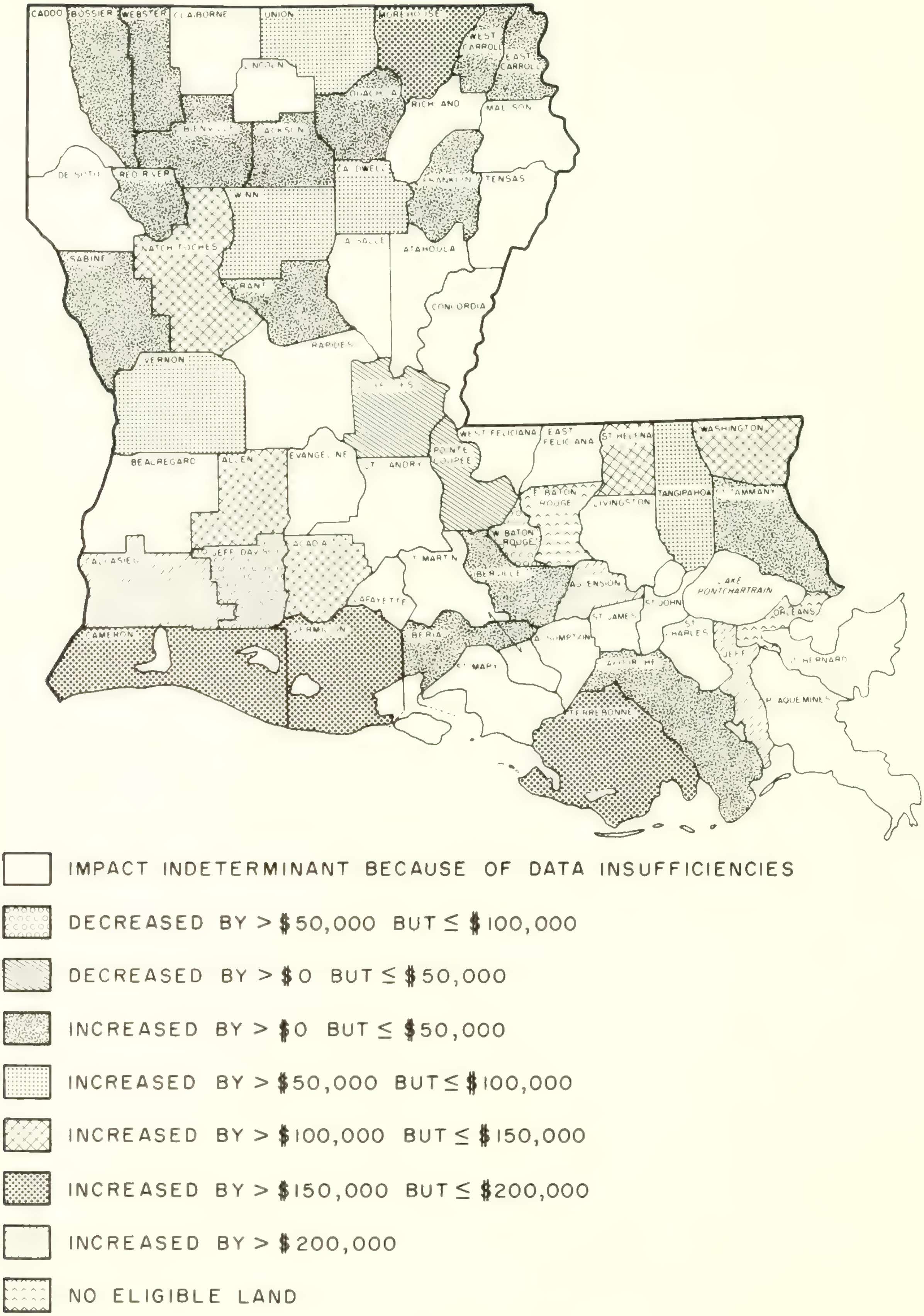


Figure 5.—*Impacts of use valuation on total property tax revenues in Louisiana parishes, 1978.*

+.31, +.26 and +.20 percent, respectively, were observed. For all enrolled lands combined, total receipts from throughout the state increased by only .77 percent—i.e. .31 + .26 + .20.

Figure 6 summarizes all available information about how total property tax revenues were changed, on a percentage basis, by the adoption of use valuation within individual parishes. The figure indicates that 18 parishes experienced revenue increases of less than or equal to 2.5 percent; 10 had increases of between 2.5 and 5.0 percent; 3 had increases of between 5.0 and 7.5 percent; and 1—St. Helena—had an increase of over 10.0 percent. Of those parishes for which the revenue impacts were quantifiable, only four experienced revenue declines. In none of these cases did the amount of revenue lost exceed 2.5 percent of the total taxes collectible given market valuation of all taxable property.

Redistributional Consequences

As noted in the methodology section, the tax-shifting effects of adopting use valuation were measured in three ways: (1) the change in the tax rate required to maintain revenue stability, (2) the total dollar amount of taxes shifted, and (3) the percent of the total tax burden shifted. Regardless of the measure used, the results of the analysis indicate that the short-run redistributional effects of the state's use value law were, for the most part, minor. Furthermore, the direction of the tax-shift was, in most cases, from the owners of ineligible and nonparticipating properties to program participants.

Change in Tax Rates.—Column 1 of table 7 shows that because participating lands in the state were assessed on the basis of use in 1978, it was possible to raise desired revenues using an average milling rate of .48 mills less than the rate which would have been required with market valuation. The portions of the decrease expressly attributable to the use assessment of forest, agricultural, and marsh lands were .16 mills, .20 mills, and .12 mills, respectively. These data imply that any person with ineligible property assessed at $10,000 paid $4.80 less in taxes as a result of the new valuation basis. On the average, $1.60 of this decrease was due to enrolled forest lands, $2.00 to enrolled agricultural lands, and $1.20 to enrolled marsh.

Information concerning the tax rate changes occurring within individual parishes is summarized in figure 7. Of the 36 parishes where the changes could be estimated, maintenance of revenue stability called for lower millage rates in 32 and higher rates in four. When higher rates were needed, the increase never exceeded 2.0 mills. When lower rates were needed, in 23 cases the decrease was 2.0 mills or less, in 7 cases it was between 2.0 and 4.0 mills, and in 2 cases it exceeded 4.0 mills. Reference to appendix table 8 shows that for St. Helena Parish, the average tax rate had to decline by 6.08 mills in order to keep revenues constant as use valuation was implemented. This means for each $10,000 of assessed valuation, the tax bills of ineligible and nonparticipating property owners in this parish were reduced by $60.80/year.

Amount of Taxes Shifted.—Column 2 of table 7 indicates that in 1978 nonparticipating property owners in Louisiana paid nearly $4.0 million less in taxes because of the state's use value program. Since total revenues were held constant during the analysis, it is appropriate to infer this tax obligation was transferred to the program's participants. Of the total tax-shift, approximately $1.3 million was due to the use assessment of enrolled forest lands, $1.6 million to the use assessment of enrolled agricultural lands, and $1.0 million to the use assessment of enrolled marsh.

Table 7.—*Alternative measures of the tax-shifting attributable to adoption of use valuation in Louisiana, 1977 to 1978*

Type land	(1) Change in tax rate required because of use valuation	(2) Amount of taxes shifted because of use valuation	(3) Percent of total tax burden shifted because of use valuation
	mills	*dollars*	*percent*
Forest	–0.16	–1,307,642	–0.24
Agricultural[1]	–0.20	–1,578,056	–0.30
Marsh	–0.12	–992,022	–0.19
Total	–0.48	–3,877,720	–0.73

[1] Includes horticultural land.

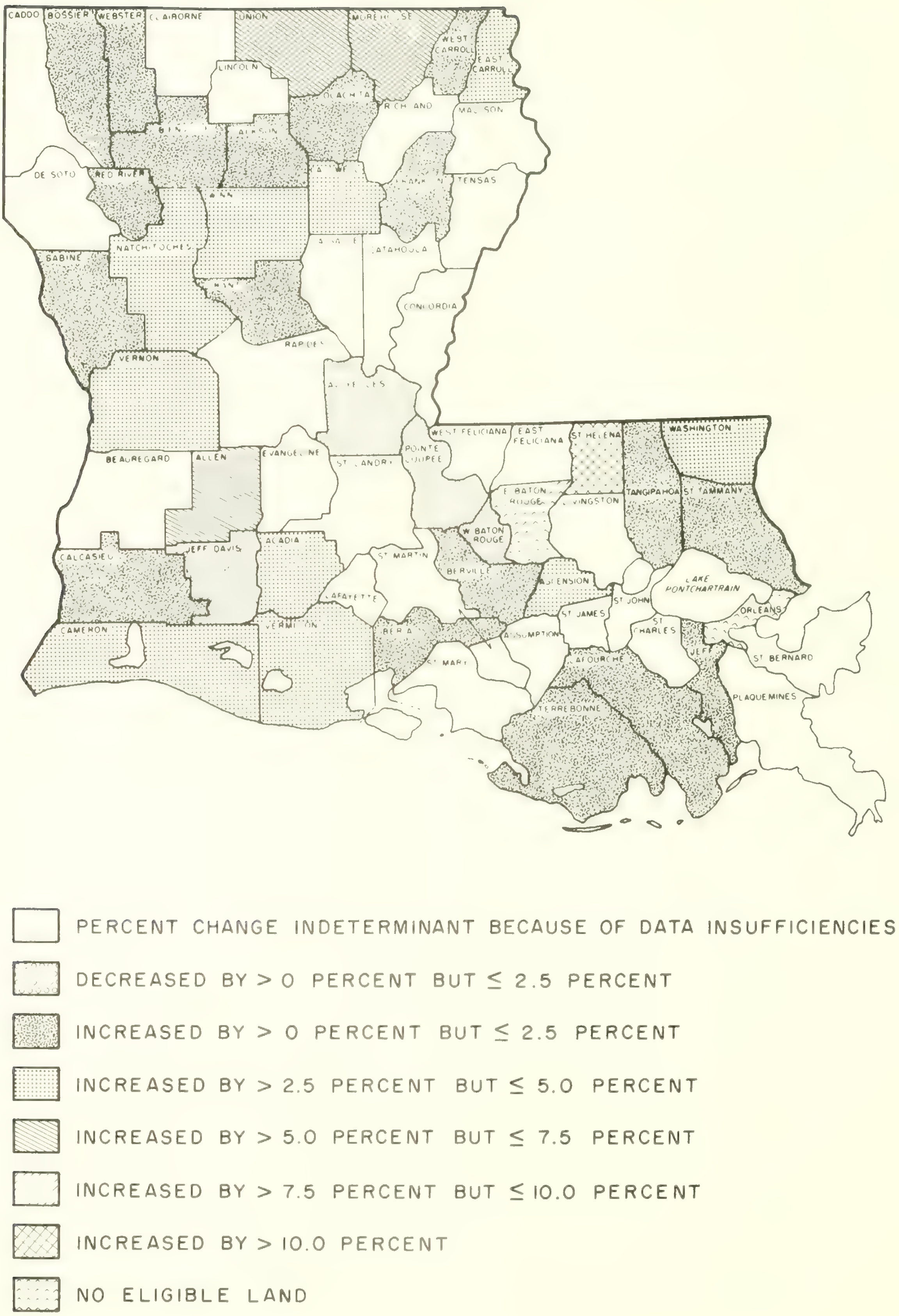
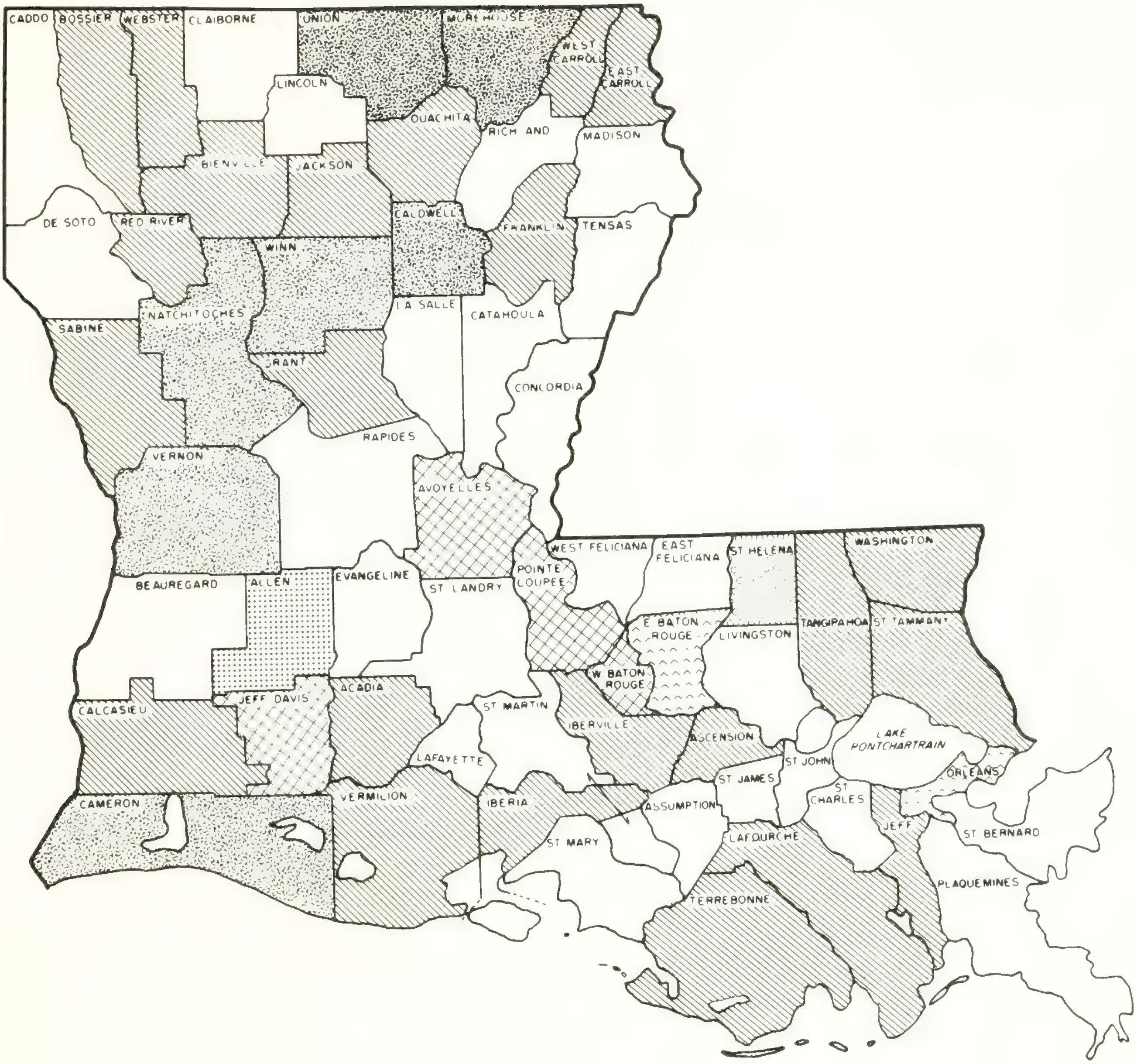


Figure 6.—*Percentage change in total property tax revenues attributable to use valuation in Louisiana parishes, 1978.*



□ CHANGE INDETERMINANT BECAUSE OF DATA INSUFFICIENCIES

░ DECREASED BY > 6.0 MILLS

▦ DECREASED BY > 4.0 MILLS BUT ≤ 6.0 MILLS

▒ DECREASED BY > 2.0 MILLS BUT ≤ 4.0 MILLS

▨ DECREASED BY > 0.0 MILLS BUT ≤ 2.0 MILLS

▩ INCREASED BY > 0.0 MILLS BUT ≤ 2.0 MILLS

▤ NO ELIGIBLE PROPERTY

Figure 7.—*Change in tax rate required to maintain revenue stability given use valuation in Louisiana parishes, 1977 to 1978.*

Within individual parishes, as for the state-as-a-whole, ineligible and nonparticipating property owners generally benefited from the adoption of use valuation. Of those parishes for which quantitative estimates could be developed, figure 8 shows in 32 cases nonparticipants paid fewer taxes, while in four they paid more. Where tax savings were realized, in 16 instances the amount saved did not exceed $50,000/year, in 5 it was between $50,000 and $100,000/year, in another 5 it ranged from $100,000 to $150,000/year, in 3 it varied between $150,000 and $200,000/year, and in another 3 it exceeded $200,000 annually. Where added tax obligations were incurred, in no case were ineligible property owners required to pay over $100,000 in additional taxes.

Percent of Tax Burden Shifted.—In absolute terms, the tax-shifts noted above appear to be substantial, at least for the state and selected parishes. However, when these shifts are expressed as percentages of total property tax collections, it becomes evident that the redistributive effects of the state's use value law were, with few exceptions, insignificant. From a statewide perspective, column 3 of table 7 shows that in 1978 the use assessment of all enrolled lands caused the proportion of the total property tax load borne by nonparticipants to decline by only .73 percent. Of this total shift, .24 percent was attributable to the use assessment of forest land, .30 percent to the use assessment of agricultural land, and .19 percent to the use assessment of marsh.

Consistent with the preceding findings, of the 36 parishes where the tax-shifts were quantifiable, implementation of use valuation caused nonparticipants to bear a higher proportion of the total property tax load in only four cases. As shown in figure 9, in none of these instances did the tax shift exceed 2.5 percent of all tax receipts. In the remaining 32 parishes, nonparticipants collectively bore a smaller proportion of the total tax burden. In 20 cases the tax shift was less than 2.5 percent, in 9 the shift was between 2.5 and 5.0 percent, in 2 it was between 5.0 and 7.5 percent, and in 1—St. Helena Parish—it exceeded 7.5 but not 10.0 percent.

DISCUSSION

To conclude, two questions are addressed. First, how do the results of this study compare with those obtained from similar studies conducted in other states and how can differences, if any, be explained? Secondly, what are the implications of the study results for those concerned with Louisiana's use value law—i.e. participating property owners, ineligible and nonparticipating property owners, local units of government, and the state's public policy-makers?

Predictability of Study Findings

The results of this investigation differ substantially from results of similar studies performed in other states. One unexpected finding was the extremely high first year enrollment level. In most states with optional statutes, participation tends to increase gradually for a few years following authorization of use valuation. To illustrate, 4 years after passage of the enabling legislation, only 3.2 percent of all qualifying lands were being so assessed in Tennessee (Hickman 1982). The time needed for landowners to learn about and evaluate a new law makes such low initial enrollments normal. The principal explanation for the high participation level observed in Louisiana seems to be that local tax officials have administered the state's use value program as if it were mandatory. Instead of waiting for applications, assessors have tended to automatically extend use assessment to qualifying lands. For the most part, this behavior can be attributed to conflicting expressions of legislative intent. As noted earlier, the language of the state constitution implies that agricultural, horticultural, marsh and timber lands *shall be* assessed on the basis of use. At the same time, the language of Act 702, which describes in detail how the state's use value program is to operate, makes participation entirely voluntary.

A second unexpected finding was that use valuation caused the assessments and taxes of participating property owners to increase. In most states, adoption of use valuation has tended to lower both of these variables, sometimes quite dramatically. Again referring to the situation in Tennessee, data show that for all enrolled properties, average assessments and taxes were reduced by almost 50 percent as a consequence of switching to use valuation (Hickman 1982). Given that the primary goal of most use value statutes is to encourage the retention of forest, farm and other open space lands, an easing of the tax pressure being exerted on such lands is considered normal. Indeed, it is difficult to conceive of a situation where use assessment would cause the taxes of enrolled properties to increase.[9] That such a relationship was observed in this study can only be explained in two ways.[10] One possibility is that use

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[9] In very rural countries, market value and use value should be equal. As residential and/or commercial development begins to occur—forest, farm and marsh lands should begin to assume market values which exceed their use values.

[10] The fact that 98 percent of all eligible lands are enrolled, even though the effect of such enrollment is generally to increase the amount of tax due, tends to confirm the supposition that parish assessors are treating the law as mandatory.

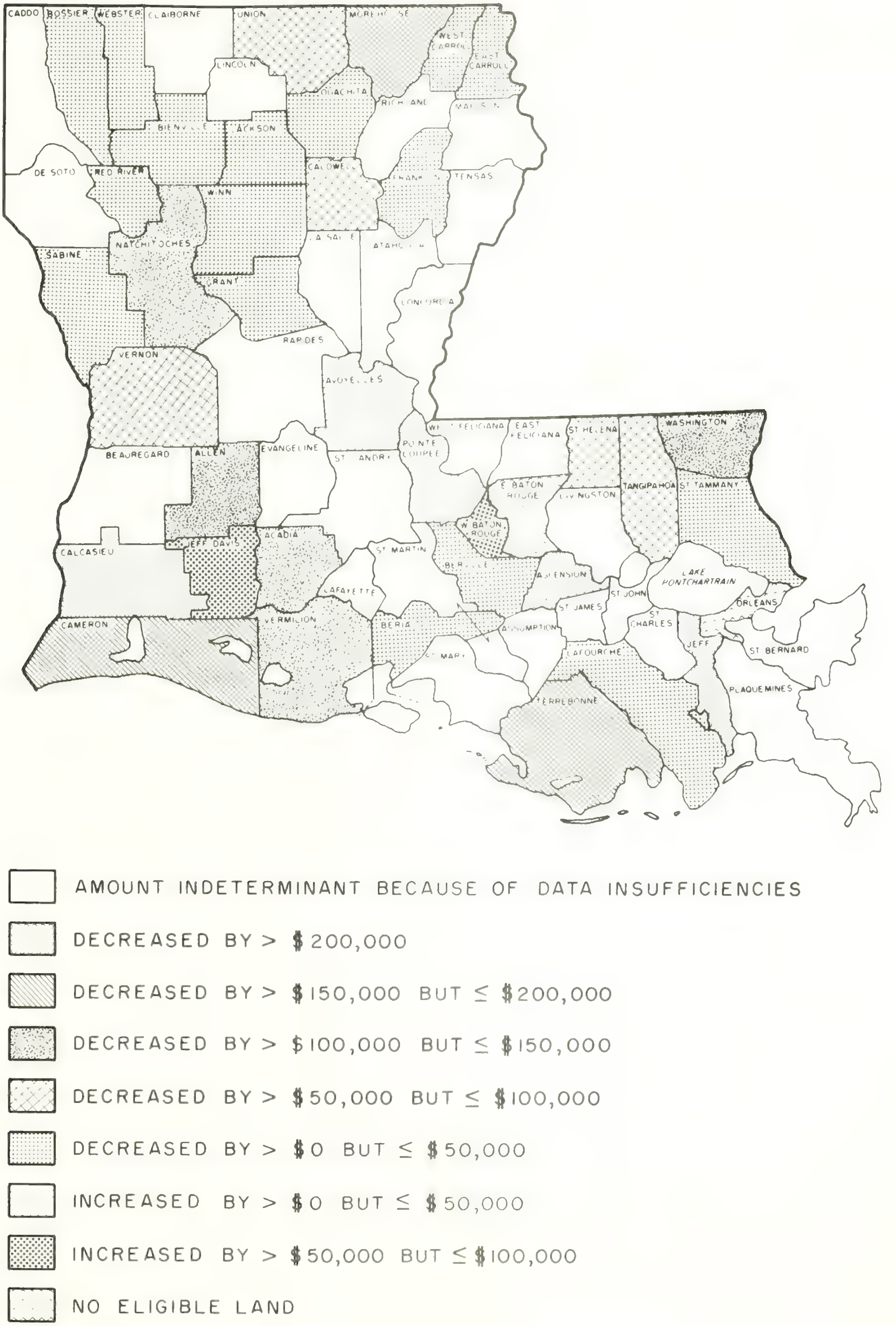

Figure 8.—*Amount of taxes shifted because of use valuation in Louisiana parishes, 1977 to 1978.*

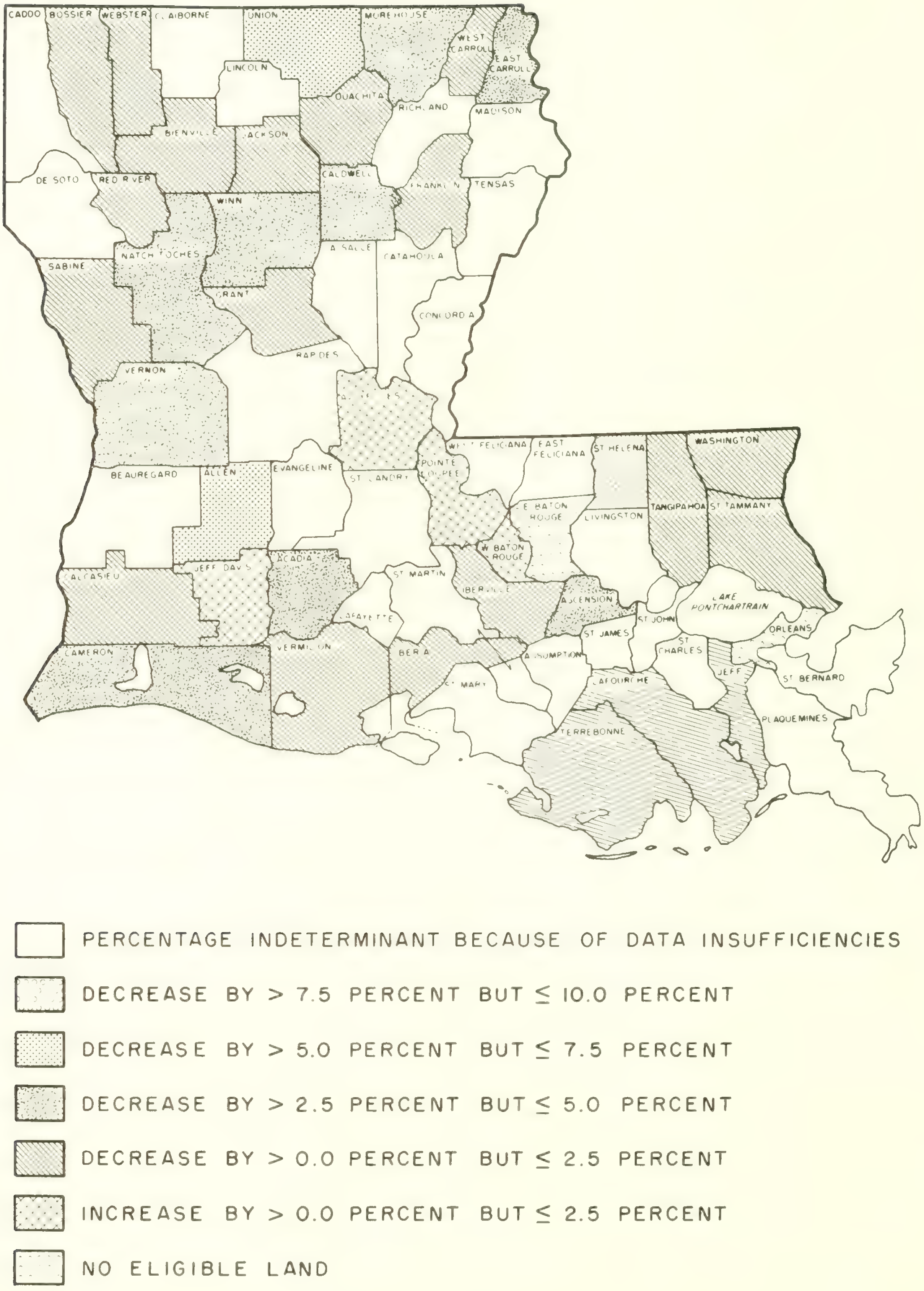

Figure 9.—*Percent of total tax burden shifted because of use valuation in Louisiana parishes, 1977 to 1978.*

value assessments in 1978 tended to overstate true use values. As previously noted, there is little evidence to suggest that this was the case. In general, the use value figures adopted that year appear to have been reasonable. Furthermore, they were based upon sound and uniformly applied valuation principles. The second possible explanation, more plausible, is that market based assessments in 1977 generally understated true market values. Facts supporting this latter explanation include the following: (1) the policies that governed the distribution of state funds to support public education and to offset the revenue losses attributable to the homestead exemption tended to encourage underassessment,[11] and (2) prior to 1978 the state exercised little or no control over individual parish assessors.

Two final unexpected findings pertain to the tax revenue and tax-shifting effects of adopting use valuation. Regarding tax revenues, normally use value statutes reduce the total value of the tax base and, unless tax rates are increased accordingly, cause total tax collections to decline. Regarding tax-shifting, use value statutes, by granting preferential tax treatment to one group of property owners, usually cause the tax obligations of all other groups to increase. Both phenomena were observed in the previously mentioned Tennessee study. In that investigation it was estimated that in a typical county, use assessment caused total tax receipts to decline by .78 percent and nonparticipants to bear collectively an additional .74 percent of the total tax burden (Hickman 1982).

The tax revenue and tax-shifting effects observed in Louisiana run counter to what is normally expected, but are entirely consistent with the other study findings both in direction and magnitude. Concerning direction, since use assessment typically increased rural property values while leaving the values of all other properties unchanged, it logically follows that at any given millage rate, both total tax collections and the proportion of the total tax load borne by rural property owners should, as they actually did, increase. Concerning magnitude, studies show that in any taxing jurisdiction the tax revenue and tax-shifting impacts of adopting use valuation are primarily a function of two variables:

- The amounts by which the taxable values of participating properties are changed. In general, the smaller these amounts, the smaller the tax revenue and tax-shifting impacts.
- The proportion of the total tax base, as measured on a fair market value basis, which is in participating property. In general, the tax revenue and tax-shifting impacts will be smallest when the proportion of the tax base enrolled is either very low or very high.[12]

Regarding the first factor, implemention of use valuation in Louisiana generally had little effect on rural land assessments and taxes. This suggests that the observed tax revenue and tax-shifting impacts should have been, as they actually were, relatively minor. Table 8 and figure 10 indicate that, for the most part, the second factor operated so as to produce the same result. The former shows that for the entire state, participating property made up only 3.3 percent of the total tax base in 1978. The latter shows that of the 36 cases where the desired figures could be developed, only in Franklin Parish did the proportion of the tax base enrolled exceed 20 percent.

Table 8.—*Percentage of the total tax base in Louisiana—as measured on a market value basis—in different types of participating property, 1978*

Type of land	Percentage of total tax base
	percent
Forest	1.06
Agricultural[1]	2.05
Marsh	0.19
Total	3.30

[1] Includes horticultural land.

Implications of Study Findings

The results of this study indicate that, generally, Louisiana's rural property owners derived no immediate tax benefits from implementation of the state's use value program. However, if these findings are a consequence of rural land assessments under the old market based valuation system failing to reflect true market values, then it would be erroneous to conclude that such owners, who generally supported the law prior to its enactment, should now withdraw that

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[11] This can be confirmed by referring back to the arguments presented in the 1969 court case which prompted revision of the state's property tax system. This case was reviewed back in the subsection entitled "Origins of Use Valuation in Louisiana."

[12] For a full explanation of this relationship, the reader is referred to the following publication: Keene, J.C., et. al. Untaxing open space: an evaluation of the effectiveness of differential assessment of farms and open space. Washington, D.C.: Council of Environmental Quality; 1976. 401 p.

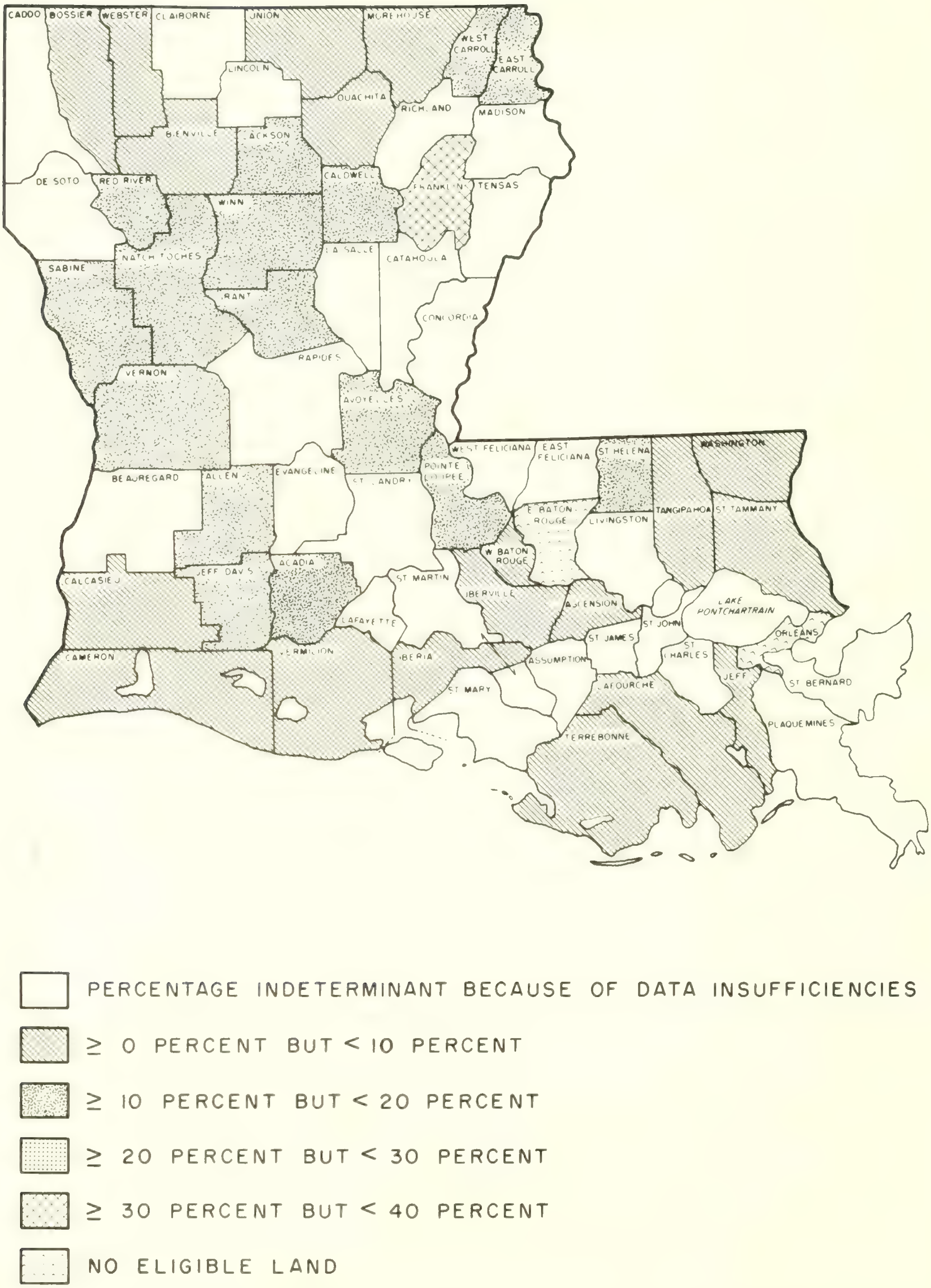

Figure 10.—*Percentage of total tax base in Louisiana parishes—as measured on a market value basis—in participating property, 1978.*

support. Rural landowners originally supported use assessment for essentially two reasons. First, a desire to insure that future tax obligations would be more predictable. Secondly, a belief that rural land taxes would increase less rapidly under use than under market valuation. At the present time it seems clear that greater predictability has been achieved. By law forest, farm and marsh land assessments are now set within narrowly defined limits for four year intervals. Furthermore, when assessment adjustments are made, they must be based upon actual product price, management cost, and/or interest rate changes. There is also some evidence indicating that rural land use values may be increasing less rapidly than market values.[13] This suggests that if the state's use value law is not currently working to the advantage of participating property owners, it probably soon will be.

Nonparticipants, ineligible property owners, and local units of government, at least in the short-run, have generally benefited from the adoption of use valuation. The first two groups found their tax burdens lowered. The latter group found it easier to raise required operating revenues. However, if future rural land assessments and taxes would be higher under market than under use valuation, then all of the impacts set-forth in this investigation will change. The owners of farm, forest and other open space lands will begin to receive tax relief; unless millage rates are increased, the tax revenues accruing to local units of government will begin to decline; and lastly, ineligible and nonparticipating property owners will begin to bear a greater proportion of the total tax burden. As the discrepancy between market and use values increased, so would the magnitude of these impacts.

Turning finally to the state's public policy makers, the results of the study point to two actions that definitely deserve consideration. These actions are:

- Resolution of the existing confusion over whether use valuation of Louisiana's rural lands is intended to be mandatory or optional. Only through such clarification can property owners and parish assessors be made fully aware of their responsibilities under the law. Failure to settle this issue could possibly leave the state's use value program open to some form of legal challenge.
- Initiation of the requirement that parish assesors retain two sets of assessment records, one showing use values and the other showing market values. While the collection of such information would add to administrative burdens and costs, it is only in this manner that the data needed to assign benefits and costs and to quantify the tax revenue and tax-shifting effects of a use value program can be obtained.

In addition to the preceding actions, if future analyses should show that extensive use of the state's use value program is causing the tax burden on ineligible and nonparticipating property owners to increase markedly, or is making it difficult for local governments to raise sufficient operating revenues, public policy-makers might have to consider still other changes in the enabling legislation. Experiences of other states suggest that the required changes could well include the following:

- Initiation of the requirement that participating landowners be subject to a penalty charge whenever they develop a property, or sell one for development. While this penalty might take any of several forms, the most common approach has been to employ a so-called "rollback tax." This charge equals, for some specified number of years not exceeding the entire period of enrollment, the difference between the taxes actually paid given use valuation and the taxes that would have been paid given market valuation.[14] The rationale for such a penalty is not that it discourages development, but that it promotes taxpayer equity. The principal idea is that since use value programs grant tax concessions to rural property owners as an inducement to retain such lands in their traditional uses, and since these concessions impose certain costs on society in terms of reducing total tax revenues and/or redistributing the total tax load, it is only fair that society should be able to recoup its costs when the lands in question are developed.

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[13] In 1982, the Louisiana Tax Commission released its Twentieth Biennial Report setting forth assessment and tax figures for the years 1980 and 1981. These data, along with those from the Nineteenth Report, show that between 1978 and 1981 average use value assessments declined for each type of qualifying property. For enrolled agricultural (including horticultural) lands the decline was $1.07/acre, or 4.23 percent; for enrolled timber lands the decline was $0.44/acre, or 4.91 percent; and for enrolled marsh lands the decline was $2.23/acre, or 29.80 percent. By contrast, the average assessments for those properties classified as "miscellaneous agricultural lands" or "miscellaneous timber lands", which by law are supposed to be based upon market value, increased during this same period. For the former the increase was $24.48/acre, or 20.95 percent. For the latter the increase was $0.28/acre, or 0.67 percent. No comparable market value assessment figures were available for marsh lands.

[14] Louisiana's use value statute formerly included a 4-year rollback tax, but this provision was dropped in 1979.

- Initiation of a system of state "subvention payments" to compensate local governments for at least some of the revenues lost as a result of extending use valuation of agricultural, horticultural, marsh and timber lands. Once again, the principal justification for this provision would be to improve taxpayer equity. As noted earlier, use assessment programs are based on the premise that they lead to important public benefits such as greater assurance of sufficient food and fiber, increased outdoor recreation opportunities, and improved air and water quality. Assuming this premise is true, it only seems fair that the costs of obtaining these benefits should be broadly distributed, and not borne solely by the ineligible property owners in those local taxing jurisdictions where the qualifying lands happen to be located. Through a system of "subvention payments," the costs of offering use valuation would be distributed over all taxpayers in the state.

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Appendix Tables

Table 1.—*Extent of adoption of use valuation in Louisiana parishes, 1978*

Parish	Amount of land assessed at use value				Proportion of all eligible land assessed at use value			
	Forest	Agric.	Marsh	Total	Forest	Agric.	Marsh	Total
	acres				*percentage*			
Acadia	38,283	307,856		346,139	100.0	86.4	....	87.8
Allen	295,135	113,779		408,914	99.6	94.7	....	98.2
Ascension	84,975	88,120	6	173,101	100.0	100.0	100.0	100.0
Assumption	143,994	79,375		223,369	100.0	96.7	....	98.8
Avoyelles	177,721	244,888	23,723	446,332	90.2	88.8	100.0	89.8
Beauregard	446,325	96,225	330	542,880	71.5	100.0	100.0	75.3
Bienville	457,570	44,971		502,541	98.3	100.0	....	98.5
Bossier	199,461	73,137	13,672	286,270	100.0	100.0	100.0	100.0
Caddo	155,636	163,722	5,178	324,536	100.0	100.0	100.0	100.0
Calcasieu	188,170	296,728	50,151	535,049	100.0	100.0	100.0	100.0
Caldwell	255,247	41,344	11,411	308,002	100.0	87.2	100.0	98.1
Cameron		103,009	580,486	683,495	....	100.0	100.0	100.0
Catahoula	179,278	218,454	37,053	434,785	100.0	99.7	100.0	99.8
Claiborne	378,268	61,873		440,141	100.0	100.0	....	100.0
Concordia	120,511	223,602	30,109	374,222	100.0	98.3	100.0	99.0
Desoto	403,543	128,951	3,002	535,496	100.0	100.0	100.0	100.0
E. Balton Rouge					....	....	....	....
E. Carroll	52,671	198,811	4,739	256,221	100.0	100.0	100.0	100.0
E. Feliciana	160,024	108,243		268,267	100.0	100.0	....	100.0
Evangeline	185,460	220,957	4,791	411,208	100.0	100.0	100.0	100.0
Franklin	99,269	282,446	5,847	387,562	100.0	100.0	100.0	100.0
Grant	205,147	41,170	7,076	253,393	100.0	82.9	100.0	96.7
Iberia	88,049	108,989	66,820	263,858	100.0	92.3	100.0	96.7
Iberville	277,370	88,364		365,734	100.0	87.3	....	96.6
Jackson	337,773	19,725		357,498	100.0	100.0	....	100.0
Jefferson			99,343	99,343	....	....	100.0	100.0
Jefferson Davis	54,668	320,577	5,664	380,909	100.0	93.0	100.0	94.0
Lafayette		121,561		121,561	....	100.0	....	100.0
Lafourche	75,892	142,864	514,379	733,135	100.0	100.0	100.0	100.0
LaSalle	316,570	14,954	995	332,519	100.0	100.0	100.0	100.0
Lincoln	233,786	31,623		265,409	100.0	100.0	....	100.0
Livingston	323,859	35,010	21,585	380,454	100.0	100.0	100.0	100.0
Madison	128,481	229,449	30,252	388,182	100.0	99.9	100.0	99.9
Morehouse	171,704	285,483	23,228	480,415	99.5	97.2	100.0	98.1
Natchitoches	418,269	205,732	14,275	638,276	100.0	99.6	100.0	99.9
Orleans				....	....	....	....	....
Ouachita	218,770	93,553	9,010	321,333	100.0	100.0	100.0	100.0
Plaquemines		10,628	518,889	529,517	....	100.0	100.0	100.0
Pointe Coupee	103,678	157,894		261,572	100.0	100.0	....	100.0
Rapides	381,197	140,718	91	522,006	100.0	99.9	100.0	100.0
Red River	121,275	98,340	11,129	230,744	100.0	90.5	100.0	95.7
Richland	64,324	237,580	36,218	338,122	99.7	99.3	100.0	99.4
Sabine	469,467	36,162		505,629	100.0	100.0	....	100.0
St. Bernard		1,569	316,060	317,629	....	100.0	100.0	100.0
St. Charles		17,895	74,226	92,121	....	100.0	100.0	100.0
St. Helena	201,267	51,694		252,961	100.0	91.0	100.0	98.0
St. James	85,636	56,324		141,960	100.0	100.0	....	100.0
St. John		16,921		16,921	....	100.0	....	100.0
St. Landry	....	321,861		321,861	....	100.0	....	100.0
St. Martin	332,969	121,231		454,200	100.0	100.0	....	100.0
St. Mary	73,333	82,481	216,116	371,930	100.0	100.0	100.0	100.0
St. Tammany	283,040	60,909	69,843	413,792	100.0	100.0	100.0	100.0
Tangipahoa	298,583	96,637	53,702	448,922	100.0	100.0	100.0	100.0
Tensas	160,114	209,996	8,172	378,282	100.0	99.8	100.0	99.9
Terrebonne	90,264	35,882	851,288	977,434	100.0	58.3	100.0	97.4
Union	481,391	49,126		530,517	100.0	100.0	....	100.0

Table 1.—*Extent of adoption of use valuation in Louisiana parishes, 1978—Continued*

Parish	Amount of land assessed at use value				Proportion of all eligible land assessed at use value			
	Forest	Agric.	Marsh	Total	Forest	Agric.	Marsh	Total
	acres				*percentage*			
Vermilion	23,955	349,280	318,874	692,109	100.0	100.0	100.0	100.0
Vernon	610,663	36,605	......	647,238	100.0	100.0	....	100.0
Washington	296,147	97,999	......	394,146	100.0	100.0	....	100.0
Webster	233,043	68,917	20,667	322,627	100.0	100.0	100.0	100.0
W. Baton Rouge	52,910	41,048	......	93,958	100.0	100.0	....	100.0
W. Carroll	34,288	188,371	......	222,659	100.0	98.3	....	98.6
W. Feliciana	154,300	57,100	16,519	227,919	100.0	100.0	100.0	100.0
Winn	464,595	18,178	......	482,773	100.0	69.9	....	98.4
Statewide	11,888,288	7,496,891	4,074,919	23,460,098	98.3	97.2	100.0	98.2

Table 2.—*Analysis of the effects of use valuation on average per acre assessments in Louisiana parishes, 1977 to 1978*[1]

Parish	Average fair market value assessments				Average current use value assessments				Change in avg. assessments due to use valuation			
	Forest	Agric.	Marsh	Total	Forest	Agric.	Marsh	Total	Forest	Agric.	Marsh	Total
	$/acre											
Acadia	15.24	26.86	....	25.57	15.29	35.13	....	32.93	+ 0.05	+ 8.27	......	+ 7.36
Allen	7.03	12.77	....	8.63	10.17	22.54	....	13.61	+ 3.14	+ 9.77	......	+ 4.98
Ascension	9.72	47.78	5.02	29.09	28.78	84.72	6.67	57.26	+19.06	+36.94	+ 1.65	+28.17
Assumption	....	26.63	....	* *	6.00	24.22	....	12.47	* *	− 2.41	......	* *
Avoyelles	5.99	31.50	1.62	19.75	7.79	27.78	5.86	18.65	+ 1.80	− 3.72	+ 4.24	− 1.10
Beauregard	5.90	9.72	....	* *	10.21	23.95	6.00	12.73	+ 4.31	+14.23	* *	* *
Bienville	7.14	7.76	....	7.20	7.73	19.80	....	8.81	+ 0.59	+12.04	......	+ 1.61
Bossier	8.00	17.91	5.21	10.40	8.14	19.63	4.60	10.91	+ 0.14	+ 1.72	− 0.61	+ 0.51
Caddo	....	25.47	....	* *	8.00	23.72	6.00	15.90	* *	− 1.75	* *	* *
Calcasieu	5.47	15.06	23.04	12.44	9.87	25.54	6.09	18.20	+ 4.40	+10.48	−16.95	+ 5.76
Caldwell	7.50	15.84	5.23	8.54	7.87	26.04	6.00	10.25	+ 0.37	+10.20	+ 0.77	+ 1.71
Cameron	....	12.90	2.78	4.31	....	21.10	5.74	8.06	......	+ 8.20	+ 2.96	+ 3.75
Catahoula	6.38	17.50	....	* *	7.84	18.97	6.00	13.27	+ 1.49	+ 1.47	* *	* *
Claiborne	....	9.39	....	* *	7.00	18.98	....	8.69	* *	+ 9.59	......	* *
Concordia	4.06	13.87	....	* *	9.24	24.13	6.01	17.88	+ 5.18	+10.26	* *	* *
Desoto	6.91	9.12	....	* *	7.70	17.96	5.00	10.15	+ 0.79	+ 8.84	* *	* *
E. Baton Rouge	12.21	65.07	22.91	* *	....	....	....	....	* *	* *	* *	* *
E. Carroll	7.46	19.38	5.03	16.66	6.35	23.54	6.00	19.68	− 1.11	+ 4.16	+ 0.97	+ 3.02
E. Feliciana	4.33	10.84	3.41	* *	8.07	21.02	....	13.30	+ 3.74	+10.18	* *	* *
Evangeline	6.13	21.37	....	* *	9.65	22.89	6.00	16.71	+ 3.52	+ 1.52	* *	* *
Franklin	9.58	22.80	4.82	19.14	9.95	23.85	6.07	20.02	+ 0.37	+ 1.05	+ 1.25	+ 0.88
Grant	6.93	20.84	2.05	9.05	8.24	24.03	3.20	10.66	+ 1.31	+ 3.19	+ 1.15	+ 1.61
Iberia	2.93	29.83	3.60	14.21	5.58	29.49	5.11	15.34	+ 2.65	− 0.34	+ 1.51	+ 1.13
Iberville	3.21	32.47	....	10.28	6.28	28.65	....	11.68	+ 3.07	− 3.82	......	+ 1.40
Jackson	7.13	8.64	....	7.21	8.18	15.89	....	8.60	+ 1.05	+ 7.25	......	+ 1.39
Jefferson	....	....	7.18	7.18	....	....	94.23	94.23	......	......	+87.05	+87.05
Jefferson Davis	16.21	28.04	12.15	26.11	9.14	24.51	5.97	22.03	− 7.07	− 3.89	− 6.18	− 4.08
Lafayette	10.87	35.09	....	* *	....	26.30	....	26.30	* *	− 8.79	......	* *
Lafourche	7.70	24.12	4.42	8.60	5.13	21.97	6.13	9.11	− 2.57	− 2.15	+ 1.71	+ 0.51
LaSalle	7.02	11.29	....	* *	8.70	17.77	5.67	9.10	+ 1.68	+ 6.48	* *	* *
Lincoln	....	7.94	....	* *	7.54	18.12	....	8.80	* *	+10.18	......	* *
Livingston	7.60	17.90	....	* *	11.97	30.76	6.07	13.36	+ 4.37	+12.86	* *	* *

Table 2.—*Analysis of the effects of use valuation on average per acre assessments in Louisiana parishes, 1977 to 1978—Continued*[1]

Parish	Average fair market value assessments				Average current use value assessments				Change in avg. assessments due to use valuation			
	Forest	Agric.	Marsh	Total	Forest	Agric.	Marsh	Total	Forest	Agric.	Marsh	Total
	$/acre											
Madison	10.03	18.16	....	* *	10.19	23.37	6.07	17.60	+ 0.16	+ 5.11	* *	* *
Morehouse	5.06	18.14	3.35	12.75	9.31	27.27	6.00	19.82	+ 4.25	+ 9.13	+ 2.65	+ 7.07
Natchitoches	7.74	20.14	4.63	11.67	8.28	26.91	6.33	14.24	+ 0.54	+ 9.77	+ 1.70	+ 2.57
Orleans	....	....	....	....	....	....	....	....	......	......	......	......
Ouachita	20.11	31.94	9.05	23.24	23.96	31.38	5.72	25.61	+ 3.85	− 0.56	− 3.33	+ 2.37
Plaquemines	134.05	31.08	3.35	* *	....	24.44	5.14	5.53	* *	− 6.64	+ 1.79	* *
Pointe Coupee	6.49	38.60	....	25.87	9.94	29.01	....	21.45	+ 3.45	− 9.59	......	− 4.42
Rapides	7.34	21.64	....	* *	8.64	28.10	5.08	13.88	+ 1.30	+ 6.46	* *	* *
Red River	8.44	20.71	4.90	13.50	9.58	22.45	6.01	14.89	+ 1.14	+ 1.74	+ 1.11	+ 1.39
Richland	....	18.80	3.05	* *	9.73	23.79	6.01	19.21	* *	+ 4.99	+ 2.96	* *
Sabine	7.00	8.21	....	7.09	7.52	16.44	....	8.16	+ 0.52	+ 8.23	......	+ 1.07
St. Bernard	13.99	76.12	2.31	* *	....	40.00	5.01	5.18	* *	−36.12	+ 2.70	* *
St. Charles	77.80	37.70	11.10	* *	....	17.81	6.32	8.55	* *	−19.89	− 4.78	* *
St. Helena	5.42	9.77	....	6.31	9.59	28.15	....	13.38	+ 4.17	+18.38	* *	+ 7.07
St. James	....	43.97	....	* *	5.08	30.83	....	15.30	* *	−13.14	......	* *
St. John	10.00	40.19	....	* *	....	29.66	....	29.66	* *	−10.53	......	* *
St. Landry	4.17	25.02	....	* *	....	26.86	....	26.86	* *	+ 1.84	......	* *
St. Martin	....	20.67	1.99	* *	7.02	24.45	....	11.67	* *	+ 3.78	* *	* *
St. Mary	....	27.31	3.56	* *	5.20	25.75	5.00	9.64	* *	− 1.56	+ 1.44	* *
St. Tammany	10.91	13.22	5.93	10.41	10.53	21.96	5.52	11.37	− 0.38	+ 8.74	− 0.41	+ 0.96
Tangipahoa	6.05	22.10	5.01	9.38	9.92	22.29	6.00	12.11	+ 3.87	+ 0.19	+ 0.99	+ 2.73
Tensas	6.82	17.78	....	* *	8.90	23.22	6.27	16.79	+ 2.08	+ 5.44	* *	* *
Terrebonne	2.47	30.77	3.16	4.11	7.92	31.15	5.00	6.23	+ 5.45	+ 0.38	+ 1.84	+ 2.12
Union	5.04	7.29	....	5.25	8.30	17.01	....	9.10	+ 3.26	+ 9.72	......	+ 3.85
Vermilion	7.95	16.73	3.55	10.35	5.79	23.22	5.55	14.48	− 2.16	+ 6.49	+ 2.00	+ 4.13
Vernon	7.16	12.17	....	7.44	8.78	19.65	....	9.40	+ 1.62	+ 7.48	......	+ 1.96
Washington	7.74	12.84	....	9.01	10.24	21.30	....	12.99	+ 2.50	+ 8.46	......	+ 3.98
Webster	6.48	8.67	4.74	6.84	6.52	13.29	4.84	7.86	+ 0.04	+ 4.62	+ 0.10	+ 1.02
W. Baton Rouge	10.00	50.87	....	27.86	10.00	30.60	....	19.00	0.00	−20.27	......	− 8.86
W. Carroll	6.93	20.67	....	18.55	10.06	22.55	....	20.62	+ 3.13	+ 1.88	......	+ 2.07
W. Feliciana	5.36	10.97	....	* *	10.10	20.35	5.08	12.31	+ 4.74	+ 9.38	* *	* *
Winn	7.06	12.40	....	7.26	8.60	18.43	....	8.97	+ 1.54	+ 6.03	......	+ 1.71
Statewide	7.21	21.98	3.74	11.33	8.97	25.30	7.61	13.95	+ 1.76	+ 3.32	+ 3.87	+ 2.62

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[1] * * Indicates no estimate possible because of lack of comparable market value (1977) and use value (1978) assessment data.

Table 3.—*Average millage rates for Louisiana parishes, 1978*

Parish	Average millage rate	Parish	Average millage rate
	mills		*mills*
Acadia	46.97	Madison	53.68
Allen	71.56	Morehouse	47.92
Ascension	43.56	Natchitoches	81.30
Assumption	36.40	Orleans	97.53
Avoyelles	46.13	Ouachita	49.74
Beauregard	68.63	Plaquemines	22.45
Bienville	61.89	Pointe Coupee	24.39
Bossier	48.29	Rapides	81.08
Caddo	57.70	Red River	37.40
Calcasieu	76.22	Richland	75.19
Caldwell	102.51	Sabine	68.97
Cameron	60.78	St. Bernard	91.24
Catahoula	69.56	St. Charles	64.26
Claiborne	40.75	St. Helena	56.55
Concordia	53.15	St. James	60.89
Desoto	24.25	St. John	88.68
E. Baton Rouge	55.04	St. Landry	32.46
E. Carroll	42.49	St. Martin	69.45
E. Feliciana	20.09	St. Mary	49.27
Evangeline	35.04	St. Tammany	65.60
Franklin	71.87	Tangipahoa	61.47
Grant	89.79	Tensas	55.65
Iberia	54.11	Terrebonne	78.87
Iberville	34.81	Union	40.86
Jackson	72.37	Vermilion	52.61
Jefferson	77.74	Vernon	70.63
Jefferson Davis	47.29	Washington	66.96
Lafayette	40.24	Webster	50.97
Lafourche	73.69	W. Baton Rouge	65.25
LaSalle	74.87	W. Carrolll	52.37
Lincoln	39.74	W. Feliciana	39.93
Livingston	93.24	Winn	63.69
		Statewide	64.40

Table 4.—*Analysis of the effect of use valuation on average per acre taxes in Louisiana parishes, 1977 to 1978*[1]

Parish	Average fair market value taxes				Average current use value taxes				Change in average taxes due to use valuation			
	Forest	Agric.	Marsh	Total	Forest	Agric.	Marsh	Total	Forest	Agric.	Marsh	Total
	$/acre											
Acadia	0.72	1.26	. . . .	1.20	0.73	1.65	. . . .	1.55	+0.01	+0.39	. . . . . .	+0.35
Allen	0.50	0.91	. . . .	0.62	0.73	1.61	. . . .	0.97	+0.23	+0.70	. . . . . .	+0.35
Ascension	0.42	2.08	0.22	1.27	1.25	3.69	0.29	2.49	+0.83	+1.61	+0.07	+1.22
Assumption	. . . .	0.97	. . . .	* *	0.22	0.88	. . . .	0.45	* *	−0.09	. . . . . .	* *
Avoyelles	0.28	1.45	0.08	0.91	0.36	1.28	0.27	0.86	+0.08	−0.17	+0.19	−0.05
Beauregard	0.40	0.67	. . . .	* *	0.70	1.64	0.41	0.87	+0.30	+0.97	* *	* *
Bienville	0.44	0.48	. . . .	0.45	0.48	1.22	. . . .	0.54	+0.04	+0.74	. . . . . .	+0.09
Bossier	0.39	0.86	0.25	0.50	0.40	0.95	0.22	0.52	+0.01	+0.09	−0.03	+0.02
Caddo	. . . .	1.47	. . . .	* *	0.46	1.37	0.35	0.92	* *	−0.10	* *	* *
Calcasieu	0.42	1.15	1.76	0.95	0.75	1.95	0.46	1.39	+0.33	+0.80	−1.30	+0.44
Caldwell	0.77	1.62	0.54	0.88	0.81	2.67	0.62	1.05	+0.04	+1.05	+0.08	+0.17
Cameron	. . . .	0.78	0.17	0.26	. . . .	1.28	0.35	0.49	. . . . . .	+0.50	+0.18	+0.23
Catahoula	0.44	1.22	. . . .	* *	0.54	1.32	0.42	0.92	+0.10	+0.10	* *	* *
Claiborne	. . . .	0.38	. . . .	* *	0.28	0.77	. . . .	0.35	* *	+0.39	. . . . . .	* *
Concordia	0.22	0.74	. . . .	* *	0.49	1.28	0.32	0.95	+0.27	+0.54	* *	* *
Desoto	0.17	0.22	. . . .	* *	0.19	0.44	0.12	0.25	+0.02	+0.22	* *	* *
E. Baton Rouge	0.67	3.58	1.26	* *	. . . .	. . . .	. . . .	. . . .	* *	* *	* *	* *
E. Carroll	0.32	0.82	0.21	0.71	0.27	1.00	0.26	0.84	−0.05	+0.18	+0.05	+0.13
E. Feliciana	0.09	0.22	0.07	* *	0.16	0.42	. . . .	0.27	+0.07	+0.20	* *	* *
Evangeline	0.22	0.75	. . . .	* *	0.34	0.80	0.21	0.59	+0.12	+0.05	* *	* *
Franklin	0.69	1.64	0.35	1.38	0.72	1.71	0.44	1.44	+0.03	+0.07	+0.09	+0.06
Grant	0.62	1.87	0.18	0.81	0.74	2.16	0.29	0.96	+0.12	+0.29	+0.11	+0.15
Iberia	0.16	1.61	0.20	0.77	0.30	1.60	0.27	0.83	+0.14	−0.01	+0.07	+0.06
Iberville	0.12	1.13	. . . .	0.36	0.22	1.00	. . . .	0.41	+0.10	−0.13	. . . . . .	+0.05
Jackson	0.52	0.62	. . . .	0.52	0.59	1.15	. . . .	0.62	+0.07	+0.53	. . . . . .	+0.10
Jefferson	. . . .	. . . .	0.56	0.56	. . . .	. . . .	7.32	7.32	. . . . . .	. . . . . .	+6.76	+6.76
Jefferson Davis	0.77	1.33	0.58	1.24	0.43	1.16	0.28	1.04	−0.34	−0.17	−0.30	−0.20
Lafayette	0.44	1.41	. . . .	* *	. . . .	1.06	. . . .	1.06	* *	−0.35	. . . . . .	* *
Lafourche	0.57	1.78	0.33	0.63	0.38	1.62	0.45	0.67	−0.19	−0.16	+0.12	+0.04
LaSalle	0.53	0.84	. . . .	* *	0.65	1.33	0.42	0.68	+0.12	+0.49	* *	* *
Lincoln	. . . .	0.32	. . . .	* *	0.30	0.72	. . . .	0.35	* *	+0.40	. . . . . .	* *
Livingston	0.71	1.67	. . . .	* *	1.12	2.87	0.57	1.25	+0.41	+1.20	* *	* *
Madison	0.54	0.98	. . . .	* *	0.55	1.25	0.33	0.94	+0.01	+0.27	* *	* *
Morehouse	0.24	0.87	0.16	0.61	0.45	1.31	0.29	0.95	+0.21	+0.44	+0.13	+0.34
Natchitoches	0.63	1.64	0.38	0.95	0.67	2.19	0.52	1.16	+0.04	+0.55	+0.14	+0.21
Orleans	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . . . .	. . . . . .	. . . . . .	. . . . . .
Ouachita	1.00	1.59	0.45	1.16	1.19	1.56	0.28	1.27	+0.19	−0.03	−0.17	+0.11
Plaquemines	3.01	0.70	0.08	* *	. . .	0.55	0.12	0.12	* *	−0.15	+0.04	* *
Pointe Coupee	0.16	0.94	. . . .	0.63	0.24	0.71	. . . .	0.52	+0.08	−0.23	. . . . . .	−0.11
Rapides	0.60	1.76	. . . .	* *	0.70	2.28	0.41	1.12	+0.10	+0.52	* *	* *
Red River	0.32	0.78	0.18	0.50	0.36	0.84	0.22	0.56	+0.04	+0.06	+0.04	+0.06
Richland	. . . .	1.41	0.23	* *	0.73	1.79	0.45	1.44	* *	+0.38	+0.22	* *
Sabine	0.48	0.57	. . . .	0.49	0.52	1.13	. . . .	0.56	+0.04	+0.56	. . . . . .	+0.07
St. Bernard	1.28	6.94	0.21	* *	. . . .	3.65	0.46	0.47	* *	−3.29	+0.25	* *
St. Charles	5.00	2.42	0.71	* *	. . . .	1.14	0.41	0.55	* *	−1.28	−0.30	* *
St. Helena	0.31	0.55	. . . .	0.36	0.54	1.59	. . . .	0.76	+0.23	+1.04	. . . . . .	+0.40
St. James	. . .	2.68	. . . .	* *	0.31	1.88	. . . .	0.93	* *	−0.80	. . . . . .	* *
St. John	0.89	3.56	. . . .	* *	. . . .	2.63	. . . .	2.63	* *	−0.93	. . . . . .	* *
St. Landry	0.14	0.81	. . . .	* *	. . . .	0.87	. . . .	0.87	* *	+0.06	. . . . . .	* *
St. Martin	. . . .	1.44	0.14	* *	0.49	1.70	. . . .	0.81	* *	+0.26	* *	* *
St. Mary	. . . .	1.35	0.18	* *	0.26	1.27	0.25	0.48	* *	−0.08	+0.07	* *
St. Tammany	0.72	0.87	0.39	0.68	0.69	1.44	0.36	0.75	−0.03	+0.57	−0.03	+0.07
Tangipahoa	0.37	1.36	0.31	0.58	0.61	1.37	0.37	0.74	+0.24	+0.01	+0.06	+0.16
Tensas	0.38	0.99	. . . .	* *	0.50	1.29	0.35	0.93	+0.12	+0.30	* *	* *
Terrebonne	0.20	2.43	0.25	0.32	0.62	2.46	0.39	0.49	+0.42	+0.03	+0.14	+0.17
Union	0.21	0.30	. . . .	0.22	0.34	0.70	. . . .	0.37	+0.13	+0.40	. . . . . .	+0.15

Table 4.—*Analysis of the effect of use valuation on average per acre taxes in Louisiana parishes, 1977 to 1978—Continued*[1]

Parish	Average fair market value taxes				Average current use value taxes				Change in average taxes due to use valuation			
	Forest	Agric.	Marsh	Total	Forest	Agric.	Marsh	Total	Forest	Agric.	Marsh	Total
	$/acre											
Vermilion	0.42	0.88	0.19	0.54	0.30	1.22	0.29	0.76	–0.12	+0.34	+0.10	+0.22
Vernon	0.51	0.86	....	0.52	0.62	1.39	....	0.66	+0.11	+0.53	......	+0.14
Washington	0.52	0.86	....	0.60	0.69	1.43	....	0.87	+0.17	+0.57	......	+0.27
Webster	0.33	0.44	0.24	0.35	0.34	0.68	0.25	0.40	+0.01	+0.24	+0.01	+0.05
W. Baton Rouge	0.65	3.32	....	1.82	0.65	2.00	....	1.24	0.00	–1.32	......	–0.58
W. Carroll	0.36	1.08	....	0.97	0.53	1.18	....	1.08	+0.17	+0.10	......	+0.11
W. Feliciana	0.21	0.44	....	* *	0.40	0.81	0.20	0.49	+0.19	+0.37	* *	* *
Winn	0.45	0.79	....	0.46	0.55	1.17	....	0.57	+0.10	+0.38	......	+0.11
Statewide	0.46	1.42	0.24	0.73	0.58	1.63	0.49	0.90	+0.12	+0.21	+0.25	+0.17

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[1] * *Indicates no estimate possible because of lack of comparable market value (1977) and use value (1978) tax data.

Table 5.—*Percentage change in average per acre assessments and taxes attributable to adoption of use valuation by Louisiana parishes, 1977 to 1978*[1]

Parish	Percentage change due to			
	Forest	Agric.	Marsh	Total
	percent			
Acadia	+ 0.86	+ 30.87	....	+ 28.98
Allen	+ 45.33	+ 76.72	....	+ 57.08
Ascension	+196.85	+ 77.36	+ 32.34	+ 96.45
Assumption	* *	– 9.16	....	* *
Avoyelles	+ 29.31	– 11.77	+ 249.61	– 5.53
Beauregard	+ 74.03	+145.59	* *	* *
Bienville	+ 8.68	+154.66	....	+ 21.18
Bossier	+ 2.16	+ 10.03	– 11.85	+ 4.45
Caddo	* *	– 6.84	* *	* *
Calcasieu	+ 79.51	+ 69.58	– 73.72	+ 46.31
Caldwell	+ 5.06	+ 64.60	+ 14.77	+ 19.67
Cameron	....	+ 63.68	+ 106.18	+ 87.73
Catahoula	+ 23.04	+ 8.30	* *	* *
Claiborne	* *	+102.38	....	* *
Concordia	+125.16	+ 73.47	* *	* *
Desoto	+ 11.60	+ 98.46	* *	* *
E. Baton Rouge	* *	* *	* *	* *
E. Carroll	– 15.25	+ 21.71	+ 21.55	+ 18.22
E. Feliciana	+ 82.08	+ 92.41	* *	* *
Evangeline	+ 55.98	+ 6.89	* *	* *
Franklin	+ 4.10	+ 4.44	+ 25.82	+ 4.47
Grant	+ 19.13	+ 15.41	+ 58.60	+ 18.15
Iberia	+ 88.97	– 0.88	+ 38.47	+ 7.87
Iberville	+ 89.49	– 11.63	....	+ 13.75
Jackson	+ 14.09	+ 84.70	....	+ 19.25
Jefferson	....	....	+1209.77	+1209.77
Jefferson Davis	– 43.89	– 13.33	– 51.29	– 15.88
Lafayette	* *	– 24.94	....	* *
Lafourche	– 33.35	– 8.95	+ 37.53	+ 6.14
LaSalle	+ 23.29	+ 57.86	* *	* *
Lincoln	* *	+126.61	....	* *
Livingston	+ 57.62	+ 71.85	* *	* *
Madison	+ 1.72	+ 27.84	* *	* *
Morehouse	+ 85.75	+ 50.45	+ 80.18	+ 55.59
Natchitoches	+ 6.66	+ 41.02	+ 36.78	+ 22.06

Table 5.—*Percentage change in average per acre assessments and taxes attributable to adoption of use valuation by Louisiana parishes, 1977 to 1978—Continued*[1]

Parish	Percentage change due to			
	Forest	Agric.	Marsh	Total
	percent			
Orleans	....	....	....	....
Ouachita	+ 19.07	− 1.82	− 37.29	+ 9.84
Plaquemines	* *	− 21.40	+ 51.72	* *
Pointe Coupee	+ 51.58	− 24.66	....	− 17.27
Rapides	+ 17.19	+ 29.70	* *	* *
Red River	+ 13.00	+ 8.05	+ 22.44	+ 11.15
Richland	* *	+ 26.75	+ 96.35	* *
Sabine	+ 7.88	+ 99.24	....	+ 14.69
St. Bernard	* *	− 47.43	+ 117.97	* *
St. Charles	* *	− 52.83	− 42.66	* *
St. Helena	+ 75.57	+188.61	....	+ 111.58
St. James	* *	− 29.87	....	* *
St. John	* *	− 26.16	....	* *
St. Landry	* *	+ 7.38	....	* *
St. Martin	* *	+ 18.17	* *	* *
St. Mary	* *	− 5.82	+ 39.67	* *
St. Tammany	− 3.82	+ 65.81	− 7.30	+ 9.76
Tangipahoa	+ 64.42	+ 0.79	+ 19.56	+ 28.35
Tensas	+ 31.04	+ 30.45	* *	* *
Terrebonne	+215.32	+ 1.23	+ 57.11	+ 52.35
Union	+ 63.29	+133.33	....	+ 70.76
Vermilion	− 27.87	+ 38.71	+ 54.48	+ 40.32
Vernon	+ 22.10	+ 61.55	....	+ 26.63
Washington	+ 32.50	+ 66.08	....	+ 44.59
Webster	+ 1.82	+ 53.92	+ 3.14	+ 14.60
W. Baton Rouge	0.00	− 39.80	....	− 31.83
W. Carroll	+ 46.19	+ 9.18	....	+ 11.25
W. Feliciana	+ 89.45	+ 84.40	* *	* *
Winn	+ 22.02	+ 48.37	....	+ 23.72
Statewide	+ 25.25	+ 14.95	+ 103.82	+ 23.21

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[1] * * Indicates no estimate possible because of the lack of comparable data for the tax years 1977 and 1978.

Table 6.—*Analysis of the potential impact of use valuation on total property tax revenues in Louisiana parishes, 1978*[1]

Parish	Total revenues collectible given market valuation				Total revenues collected given use valuation				Change in total revenues due to use valuation			
	Forest	Agric.	Marsh	Total	Forest	Agric.	Marsh	Total	Forest	Agric.	Marsh	Total
	dollars											
Acadia	27,411	388,514	......	415,925	27,487	507,962	......	535,449	+ 76	+119,448	....	+119,524
Allen	148,453	103,994	......	252,447	214,858	183,526	......	398,384	+ 66,405	+ 79,532	....	+145,937
Ascension	35,944	183,378	1	219,323	106,559	325,163	2	431,724	+ 70,615	+141,785	+ 1	+212,401
Assumption	* *	76,914	......	* *	31,391	70,009	......	101,400	* *	− 6,906	....	* *
Avoyelles	49,051	355,822	1,779	406,652	63,802	313,702	6,405	383,909	+ 14,751	− 42,120	+ 4,626	− 22,743
Beauregard	180,762	64,182	* *	* *	312,875	158,194	136	471,205	+132,113	+ 94,012	* *	* *
Bienville	202,246	21,586	......	223,832	218,718	55,089	......	273,807	+ 16,472	+ 33,503	....	+ 49,975
Bossier	76,992	63,264	3,445	143,701	78,388	69,334	3,035	150,157	+ 1,396	+ 6,070	− 410	+ 7,056
Caddo	* *	240,671	* *	* *	71,904	224,135	1,792	297,831	* *	− 16,536	* *	* *
Calcasieu	78,467	340,644	88,065	507,176	141,504	577,729	23,270	742,503	+ 63,037	+237,086	− 64,795	+235,327
Caldwell	196,285	67,143	6,116	269,544	205,904	110,347	7,018	323,269	+ 9,699	+ 43,204	+ 901	+ 53,725
Cameron	......	80,759	98,102	178,861	......	132,058	202,590	334,648	....	+ 51,298	+104,487	+155,787
Catahoula	79,599	265,859	* *	* *	97,707	288,359	15,451	401,517	+ 18,108	+ 22,501	* *	* *
Claiborne	* *	23,697	......	* *	107,806	47,828	......	155,634	* *	+ 24,130	....	* *
Concordia	26,030	164,795	* *	* *	59,171	286,881	9,605	355,657	+ 33,141	+122,087	* *	* *
Desoto	67,795	28,498	* *	* *	75,463	56,223	363	132,049	+ 7,668	+ 27,724	* *	* *
E. Baton Rouge	* *	* *	* *	* *	......	......	......	......	* *	* *	* *	* *
E. Carroll	16,697	163,621	1,014	181,332	14,221	198,811	1,208	214,240	− 2,476	+ 35,190	+ 194	+ 32,908
E. Feliciana	13,922	23,597	* *	* *	25,924	45,679	......	71,627	+ 12,002	+ 22,082	* *	* *
Evangeline	39,874	165,497	* *	* *	62,685	177,208	1,006	240,899	+ 22,811	+ 11,711	* *	* *
Franklin	68,396	462,929	2,023	533,348	70,977	484,112	2,549	557,638	+ 2,581	+ 21,183	+ 526	+ 24,290
Grant	127,601	77,029	1,302	205,932	151,809	88,845	2,031	242,685	+ 24,208	+ 11,816	+ 729	+ 36,753
Iberia	14,000	175,908	13,030	202,938	26,591	173,946	18,509	219,046	+ 12,591	− 1,962	+ 5,479	+ 16,108
Iberville	32,730	99,851	......	132,581	60,744	88,099	......	148,843	+ 28,014	− 11,752	....	+ 16,262
Jackson	174,291	12,328	......	186,619	199,962	22,684	......	222,646	+ 25,671	+ 10,356	....	+ 36,027
Jefferson	......	......	55,433	55,433	......	......	727,687	727,687	....	....	+672,254	+672,254
Jefferson Davis	41,930	425,085	3,257	470,272	23,617	371,549	1,597	396,763	− 18,313	− 53,536	− 1,660	− 73,509
Lafayette	* *	171,644	......	* *	......	128,612	......	128,612	* *	− 43,033	....	* *
Lafourche	43,031	253,869	167,688	464,588	28,687	231,297	232,499	492,483	− 14,344	− 22,573	+ 64,812	+ 27,895
LaSalle	166,516	12,636	* *	* *	206,087	19,889	423	226,399	+ 39,571	+ 7,253	* *	* *
Lincoln	* *	9,993	......	* *	70,136	22,769	......	92,905	* *	+ 12,776	....	* *
Livingston	229,616	58,432	* *	* *	361,427	100,409	12,217	474,053	+131,811	+ 41,977	* *	* *
Madison	69,123	223,713	* *	* *	70,279	286,582	9,862	366,723	+ 1,156	+ 62,869	* *	* *
Morehouse	41,552	248,085	3,740	293,377	76,580	373,126	6,690	456,396	+ 35,028	+125,042	+ 2,950	+163,019
Natchitoches	263,091	336,783	5,367	605,241	281,495	450,142	7,352	738,989	+ 18,404	+113,358	+ 1,984	+133,748
Orleans	......	......	......	......	......	......	......	......	....	....	....	....
Ouachita	218,770	148,656	4,055	371,481	260,774	146,036	2,568	409,378	+ 42,004	− 2,619	− 1,487	+ 37,897
Plaquemine	* *	7,418	38,917	* *	......	5,835	59,672	65,507	* *	− 1,584	+ 20,756	* *
Pointe Coupee	16,381	148,578	......	164,959	25,090	111,789	......	136,879	+ 8,709	− 36,789	....	− 28,080
Rapides	226,812	246,960	* *	* *	267,219	320,556	37	587,812	+ 40,407	+ 73,596	* *	* *
Red River	38,323	76,214	2,037	116,574	43,416	82,606	2,504	128,526	+ 5,093	+ 6,392	+ 467	+ 11,952
Richland	* *	335,938	8,294	* *	47,085	425,031	16,371	488,487	* *	+ 89,093	+ 8,077	* *

Table 6.—*Analysis of the potential impact of use valuation on total property tax revenues in Louisiana parishes, 1978—Continued*[1]

Parish	Total revenues collectible given market valuation				Total revenues collected given use valuation				Change in total revenues due to use valuation			
	Forest	Agric.	Marsh	Total	Forest	Agric.	Marsh	Total	Forest	Agric.	Marsh	Total
	dollars											
Sabine	226,753	20,468	......	247,221	243,653	41,008	......	284,661	+ 16,900	+ 20,540	......	+ 37,440
St. Bernard	* *	10,897	66,689	* *	......	5,727	144,439	150,166	* *	− 5,170	+ 77,751	* *
St. Charles	* *	43,360	52,923	* *	......	20,472	30,136	50,608	* *	− 22,888	− 22,787	* *
St. Helena	61,789	28,535	......	90,324	109,087	82,297	......	191,384	+ 47,298	+ 53,762	......	+101,060
St. James	* *	150,779	......	* *	26,462	105,720	......	132,182	* *	− 45,059	......	* *
St. John	* *	60,306	......	* *	......	44,502	......	44,502	* *	− 15,804	......	* *
St. Landry	* *	261,351	......	* *	......	280,663	......	280,663	* *	+ 19,312	......	* *
St. Martin	* *	174,088	* *	* *	162,489	205,850	......	368,339	* *	+ 31,763	* *	* *
St. Mary	* *	111,019	37,820	* *	18,773	104,668	53,165	176,606	* *	− 6,351	+ 15,344	* *
St. Tammany	202,657	52,808	27,169	282,634	195,581	87,770	25,283	308,634	− 7,076	+ 34,962	− 1,886	+ 26,000
Tangipahoa	111,073	131,233	16,540	258,846	182,136	132,393	19,816	334,345	+ 71,063	+ 1,160	+ 3,276	+ 75,499
Tensas	60,843	207,686	* *	* *	79,256	271,315	2,852	353,423	+ 18,413	+ 63,629	* *	* *
Terrebonne	17,601	87,087	211,971	316,659	56,415	88,162	335,407	479,984	+ 38,814	+ 1,076	+123,436	+163,325
Union	99,167	14,640	......	113,807	163,192	34,143	......	197,335	+ 64,025	+ 19,503	......	+ 83,528
Vermillion	10,013	307,366	59,629	377,008	7,306	426,820	93,111	527,237	− 2,707	+119,454	+ 33,482	+150,229
Vernon	308,980	31,480	......	340,460	378,592	50,808	......	429,400	+ 69,612	+ 19,327	......	+ 88,940
Washington	153,404	84,279	......	237,683	203,157	139,747	......	342,904	+ 49,753	+ 55,467	......	+105,221
Webster	76,904	30,461	5,001	112,366	77,370	46,657	5,105	129,132	+ 466	+ 16,195	+ 104	+ 16,766
W. Baton Rouge	34,497	136,238	......	170,735	34,497	81,973	......	116,470	0	− 54,265	......	− 54,265
W. Carroll	12,447	203,817	......	216,264	18,070	222,466	......	240,536	+ 5,623	+ 18,649	......	+ 24,272
W. Feliciana	33,020	25,010	* *	* *	62,183	46,422	3,353	111,958	+ 29,163	+ 21,413	* *	* *
Winn	209,068	14,361	......	223,429	254,598	21,341	......	275,939	+ 45,530	+ 6,980	......	+ 52,510
Statewide	5,516,166	10,615,598	982,055	17,113,819	6,871,430	12,212,435	1,996,710	21,080,575	+1,355,264	+1,596,837	+1,014,655	+3,966,756

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[1] * * Indicates no estimate possible because of the lack of comparable data for tax years 1977 and 1978.

Table 7.—*Percentage change in total property tax revenues attributable to adoption of use valuation by Louisiana parishes, 1978*[1]

Parish	Tot. revenue collectible given market valuation of all tax. prop.	Percentage change due to			
		Forest	Agric.	Marsh	Total
	dollars	*percent*			
Acadia	4,135,430	0.00	+2.89	.....	+2.89
Allen	2,050,396	+3.24	+3.88	.....	+7.12
Ascension	5,172,679	+1.37	+2.74	0.00	+4.11
Assumption	* *	* *	* *	* *	* *
Avoyelles	2,410,230	+0.61	–1.75	+0.19	–0.95
Beauregard	* *	* *	* *	* *	* *
Bienville	2,350,571	+0.70	+1.43	.....	+2.13
Bossier	6,087,554	+0.03	+0.10	–0.01	+0.12
Caddo	* *	* *	* *	* *	* *
Calcasieu	30,690,612	+0.21	+0.77	–0.21	+0.77
Caldwell	1,726,121	+0.56	+2.50	+0.05	+3.11
Cameron	3,723,521	.....	+1.38	+2.81	+4.19
Catahoula	* *	* *	* *	* *	* *
Claiborne	* *	* *	* *	* *	* *
Concordia	* *	* *	* *	* *	* *
Desoto	* *	* *	* *	* *	* *
E. Baton Rouge	* *	* *	* *	* *	* *
E. Carroll	922,823	–0.27	+3.81	+0.02	+3.56
E. Feliciana	* *	* *	* *	* *	* *
Evangeline	* *	* *	* *	* *	* *
Franklin	2,635,621	+0.10	+0.80	+0.02	+0.92
Grant	1,651,876	+1.47	+0.72	+0.04	+2.23
Iberia	6,114,999	+0.21	–0.03	+0.09	+0.27
Iberville	3,925,798	+0.74	–0.31	.....	+0.43
Jackson	1,791,540	+1.43	+0.58	.....	+2.01
Jefferson	66,688,355	.....	.....	+1.01	+1.01
Jefferson Davis	3,366,051	–0.54	–1.59	–0.05	–2.18
Lafayette	* *	* *	* *	* *	* *
Lafourche	10,768,232	–0.13	–0.21	+0.60	+0.26
LaSalle	* *	* *	* *	* *	* *
Lincoln	* *	* *	* *	* *	* *
Livingston	* *	* *	* *	* *	* *
Madison	* *	* *	* *	* *	* *
Morehouse	3,254,300	+1.08	+3.84	+0.09	+5.01
Natchitoches	4,373,693	+0.42	+2.59	+0.05	+3.06
Orleans	99,402,055	.....	.....	.....	.....
Ouachita	12,269,828	+0.36	–0.02	–0.01	+0.33
Plaquemines	* *	* *	* *	* *	* *
Pointe Coupee	1,135,119	+0.77	–3.24	.....	–2.47
Rapides	* *	* *	* *	* *	* *
Red River	590,152	+0.86	+1.08	+0.08	+2.02
Richland	* *	* *	* *	* *	* *
Sabine	2,135,852	+0.79	+0.96	.....	+1.75
St. Bernard	* *	* *	* *	* *	* *
St. Charles	* *	* *	* *	* *	* *
St. Helena	890,378	+5.31	+6.04	.....	+11.35
St. James	* *	* *	* *	* *	* *
St. John	* *	* *	* *	* *	* *
St. Landry	* *	* *	* *	* *	* *
St. Martin	* *	* *	* *	* *	* *
St. Mary	* *	* *	* *	* *	* *
St. Tammany	9,405,584	–0.08	+0.37	–0.02	+0.27
Tangipahoa	5,701,971	+1.25	+0.02	+0.06	+1.33
Tensas	* *	* *	* *	* *	* *
Terrebonne	18,824,696	+0.21	+0.01	+0.66	+0.88
Union	1,442,123	+4.44	+1.35	.....	+5.79

Table 7.—*Percentage change in total property tax revenues attributable to adoption of use valuation by Louisiana parishes, 1978—Continued*[1]

Parish	Tot. revenue collectible given market valuation of all tax. prop.	Percentage change due to Forest	Agric.	Marsh	Total
	dollars	*percent*			
Vermilion	6,304,258	–0.04	+1.89	+0.53	+2.38
Vernon	2,716,616	+2.56	+0.71	. . . . .	+3.27
Washington	3,986,254	+1.25	+1.39	. . . . .	+2.64
Webster	3,074,306	+0.02	+0.53	0.00	+0.55
W. Baton Rouge	2,505,291	0.00	–2.17	. . . . .	–2.17
W. Carroll	1,281,115	+0.44	+1.46	. . . . .	+1.90
W. Feliciana	* *	* *	* *	* *	* *
Winn	1,527,804	+2.98	+0.46	. . . . .	+3.44
Statewide	518,300,631	+0.26	+0.31	+0.20	+0.77

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[1] * * Indicates no estimate possible because of the lack of comparable data for the tax years 1977 and 1978.

Table 8.—*Alternative measures of the tax-shifting attributable to adoption of use valuation in Louisiana parishes, 1977 to 1978*[1]

Parish	Change in tax rate required because of use valuation				Amount of taxes shifted because of use valuation				Pct. of tot. tax burden shifted because of use valuation			
	Forest	Agric.	Marsh	Total	Forest	Agric.	Marsh	Total	Forest	Agric.	Marsh	Total
	mills				dollars				percent			
Acadia	0.00	–1.35	.....	–1.35	–44	–108,037	....	–108,081	0.00	–2.55	.....	–2.55
Allen	–2.23	–2.69	.....	–4.92	–61,737	–75,671	....	–137,408	–2.80	–3.45	.....	–6.25
Ascension	–0.58	–1.18	0.00	–1.76	–70,178	–136,955	–1	–207,134	–1.30	–2.54	0.00	–3.84
Assumption	**	+0.15	.....	**	**	+6,633	....	**	**	+0.40	.....	**
Avoyelles	–0.29	+0.79	–0.09	+0.41	–14,516	+35,729	–4,626	+16,587	–0.60	+1.51	–0.19	+0.72
Beauregard	–2.43	–1.78	**	**	–125,426	–94,012	**	**	–3.25	–2.48	**	**
Bienville	–0.43	–0.87	.....	–1.30	–15,236	–33,096	....	–48,332	–0.64	–1.38	.....	–2.02
Bossier	–0.01	–0.04	+0.01	–0.04	–1,300	–5,508	+405	–6,403	–0.03	–0.10	+0.01	–0.12
Caddo	**	+0.03	**	**	**	+15,645	**	**	**	+0.06	**	**
Calcasieu	–0.16	–0.59	+0.16	–0.59	–63,037	–234,621	+64,730	–232,928	–0.21	–0.76	+0.21	–0.76
Caldwell	–0.59	–2.56	–0.06	–3.21	–9,016	–41,613	–896	–51,525	0.50	–2.33	–0.05	–2.88
Cameron	.....	–0.82	–1.68	–2.50	....	–50,361	–101,705	–152,066	.....	–1.29	–2.62	–3.91
Catahoula	–0.96	–1.18	**	**	–17,064	–17,743	**	**	–1.28	–1.33	**	**
Claiborne	**	–0.77	.....	**	**	–23,806	....	**	**	–1.81	.....	**
Concordia	–0.92	–3.54	**	**	–32,740	–110,848	**	**	–1.68	–5.69	**	**
Desoto	–0.23	–0.84	**	**	–7,108	–26,715	**	**	–0.86	–3.22	**	**
E. Baton Rouge	**	**	**	**	**	**	**	**	**	**	**	**
E. Carroll	+0.11	–1.62	–0.01	–1.52	+2,442	–28,876	–194	–26,628	+0.25	–3.02	–0.02	–2.79
E. Feliciana	–0.48	–0.91	**	**	–11,650	–21,101	**	**	–2.28	–4.11	**	**
Evangeline	–0.43	–0.21	**	**	–22,364	–10,448	**	**	–1.19	–0.57	**	**
Franklin	–0.07	–0.58	–0.01	–0.66	–2,558	–17,574	–447	–20,579	–0.10	–0.66	–0.02	–0.78
Grant	–1.30	–0.63	–0.04	–1.97	–22,254	–11,238	–727	–34,219	–1.32	–0.67	–0.04	–2.03
Iberia	–0.11	+0.02	–0.05	–0.14	–12,503	+1,924	–5,479	–16,058	–0.20	+0.03	–0.09	–0.26
Iberville	–0.26	+0.11	.....	–0.15	–28,014	+11,752	....	–16,262	–0.74	+0.31	.....	–0.43
Jackson	–1.03	–0.41	.....	–1.44	–23,147	–10,254	....	–33,401	–1.27	–0.56	.....	–1.83
Jefferson	.....	.....	–0.79	–0.79	....	....	–671,684	–671,684	.....	.....	–1.00	–1.00
Jefferson Davis	+0.26	+0.76	+0.02	+1.04	+18,012	+46,795	+1,523	+66,330	+0.55	+1.42	+0.05	+2.02
Lafayette	**	+0.17	.....	**	**	+42,268	....	**	**	+0.40	.....	**
Lafourche	+0.10	+0.16	–0.44	–0.18	+14,314	+22,497	–63,370	–26,559	+0.13	+0.20	–0.59	–0.26
LaSalle	–1.30	–0.23	**	**	–36,960	–7,161	**	**	–1.58	–0.31	**	**
Lincoln	**	–0.21	.....	**	**	–12,737	....	**	**	–0.50	.....	**
Livingston	–2.82	–0.88	**	**	–124,952	–41,440	**	**	–2.79	–0.92	**	**
Madison	–0.04	–2.41	**	**	–1,036	–52,874	**	**	–0.07	–3.62	**	**
Morehouse	–0.49	–1.82	–0.04	–2.35	–34,338	–115,559	–2,895	–152,792	–1.01	–3.38	–0.09	–4.48
Natchitoches	–0.20	–2.09	–0.03	–2.32	–10,432	–104,431	–1,814	–116,677	–0.23	–2.32	–0.04	–2.59
Orleans	.....	.....	.....	.....	....	....	....	....	**	**	**	.....
Ouachita	–0.18	+0.01	+0.01	–0.16	–42,004	+2,505	+1,487	–38,012	–0.36	+0.02	+0.01	–0.33
Plaquemines	**	+0.01	–0.09	**	**	+1,582	–20,504	**	**	+0.03	–0.41	**
Point Coupee	–0.20	+0.78	.....	+0.58	–8,578	+31,992	....	+23,414	–0.78	+2.91	.....	+2.13
Rapides	–0.23	–0.42	**	**	–39,604	–72,311	**	**	–0.27	–0.51	**	**
Red River	–0.32	–0.40	–0.03	–0.75	–4,806	–5,579	–467	–10,852	–0.80	–0.93	–0.08	–1.81
Richland	**	–2.31	–0.02	**	**	–78,987	–7,982	**	**	–2.63	–0.27	**

Table 8.—*Alternative measures of the tax-shifting attributable to adoption of use valuation in Louisiana parishes, 1977 to 1978—Continued*[1]

Parish	Change in tax rate required because of use valuation				Amount of taxes shifted because of use valuation				Pct. of tot. tax burden shifted because of use valuation			
	Forest	Agric.	Marsh	Total	Forest	Agric.	Marsh	Total	Forest	Agric.	Marsh	Total
	mills				*dollars*				*percent*			
Sabine	–0.54	–0.66	.....	–1.20	– 15,074	– 20,374	....	– 35,448	–0.69	–0.94	.....	–1.63
St. Bernard	* *	+0.05	–0.68	* *	* *	+ 5,165	– 77,225	* *	* *	+0.05	–0.74	* *
St. Charles	* *	+0.15	+0.15	* *	* *	+ 22,390	+ 22,332	* *	* *	+0.24	+0.24	* *
St. Helena	–2.84	–3.24	.....	–6.08	– 44,326	– 52,086	....	– 96,412	–4.48	–5.25	.....	–9.73
St. James	* *	+0.65	.....	* *	* *	+ 42,597	....	* *	* *	+1.00	.....	* *
St. John	* *	+0.32	.....	* *	* *	+ 15,778	....	* *	* *	+0.35	.....	* *
St. Landry	* *	–0.15	.....	* *	* *	– 18,359	....	* *	* *	–0.42	.....	* *
St. Martin	* *	–0.57	* *	* *	* *	– 30,584	* *	* *	* *	–0.77	* *	* *
St. Mary	* *	+0.03	–0.09	* *	* *	+ 5,707	– 15,308	* *	* *	+0.07	–0.18	* *
St. Tammany	+0.05	–0.24	+0.02	–0.17	+ 6,952	– 34,455	+ 1,869	– 25,634	+0.08	–0.37	+0.02	–0.27
Tangipahoa	–0.77	–0.01	–0.04	–0.82	– 69,868	– 1,000	– 3,258	– 74,126	–1.20	–0.02	–0.06	–1.28
Tensas	–1.10	–3.99	* *	* *	– 17,246	– 48,621	* *	* *	–1.83	–5.13	* *	* *
Terrebonne	–0.17	–0.01	–0.52	–0.70	– 38,792	– 1,059	–122,609	–162,460	–0.21	–0.01	–0.64	–0.86
Union	–1.79	–0.53	.....	–2.32	– 59,695	– 19,334	....	– 79,029	–3.92	–1.27	.....	–5.19
Vermilion	+0.02	–0.99	–0.27	–1.24	+ 2,582	–113,452	– 32,980	–143,850	+0.05	–1.76	–0.52	–2.23
Vernon	–1.81	–0.49	.....	–2.30	– 62,175	– 19,114	......	– 81,289	–2.21	–0.68	.	–2.89
Washington	–0.82	–0.92	.....	–1.74	– 47,638	– 54,314	......	–101,952	–1.16	–1.33	....	–2.49
Webster	–0.01	–0.27	–0.01	–0.29	– 451	– 16,096	– 103	– 16,650	–0.02	–0.52	0.00	–0.54
W. Baton Rouge	0.00	+1.41	.....	+1.40	0	+ 51,263	....	+ 51,263	0.00	+2.09	.....	+2.09
W. Carroll	–0.22	–0.75	.....	–0.97	– 5,490	– 15,552	....	– 21,042	–0.42	–1.19	.....	–1.61
W. Feliciana	–1.01	–0.73	* *	* *	– 28,372	– 20,860	* *	* *	–2.40	–1.77	* *	* *
Winn	–1.89	–0.28	.....	–2.17	– 39,382	– 6,885	....	– 46,267	–2.50	–0.44	....	–2.94
Statewide	–0.16	–0.20	–0.12	–0.48	–1,307,642	–1,578,056	–992,022	–3,877,720	–0.24	–0.30	–0.19	–0.73

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[1] * * Indicates no estimate possible because of the lack of comparable data for the tax years 1977 and 1978.

Table 9.—*Percentage of the total tax base in Louisiana parishes—as measured on a market value basis—in different types of participating property, 1978*[1]

Parish	Percentage of tax base			
	Forest	Agric.	Marsh	Total
	percent			
Acadia	0.66	9.39	....	10.05
Allen	7.24	5.07	....	12.31
Ascension	0.70	3.55	0.01	4.26
Assumption	* *	* *	* *	* *
Avoyelles	2.04	14.77	0.07	16.88
Beauregard	* *	* *	* *	* *
Bienville	8.60	0.92	....	9.52
Bossier	1.27	1.04	0.06	2.37
Caddo	* *	* *	* *	* *
Calcasieu	0.26	1.11	0.29	1.66
Caldwell	11.37	3.89	0.35	15.61
Cameron	....	2.17	2.63	4.80
Catahoula	* *	* *	* *	* *
Claiborne	* *	* *	* *	* *
Concordia	* *	* *	* *	* *
Desoto	* *	* *	* *	* *
E. Baton Rouge	* *	* *	* *	* *
E. Carroll	1.81	17.74	0.11	19.66
E. Feliciana	* *	* *	* *	* *
Evangeline	* *	* *	* *	* *
Franklin	4.38	29.65	0.13	34.16
Grant	7.73	4.66	0.08	12.47
Iberia	0.23	2.88	0.21	3.32
Iberville	0.79	2.54	....	3.83
Jackson	9.73	0.69	....	10.42
Jefferson	....	....	0.08	0.08
Jefferson Davis	1.24	12.63	0.10	13.97
Lafayette	* *	* *	* *	* *
Lafourche	0.40	2.36	1.56	4.32
LaSalle	* *	* *	* *	* *
Lincoln	* *	* *	* *	* *
Livingston	* *	* *	* *	* *
Madison	* *	* *	* *	* *
Morehouse	1.28	7.62	0.11	9.01
Natchitoches	6.17	7.69	0.12	13.98
Orleans	....	....	....	....
Ouachita	1.76	1.21	0.03	3.00
Plaquemines	* *	* *	* *	* *
Pointe Coupee	1.45	13.10	....	14.55
Rapides	* *	* *	* *	* *
Red River	6.49	12.91	0.35	19.75
Richland	* *	* *	* *	* *
Sabine	10.61	0.96	....	11.57
St. Bernard	* *	* *	* *	* *
St. Charles	* *	* *	* *	* *
St. Helena	6.93	3.21	....	10.14
St. James	* *	* *	* *	* *
St. John	* *	* *	* *	* *
St. Landry	* *	* *	* *	* *
St. Martin	* *	* *	* *	* *
St. Mary	* *	* *	* *	* *
St. Tammany	2.15	0.56	0.29	3.00
Tangipahoa	1.95	2.30	0.29	4.54
Tensas	* *	* *	* *	* *
Terrebonne	0.09	0.46	1.13	1.68
Union	6.87	1.01	....	7.88

Table 9.—*Percentage of the total tax base in Louisiana parishes—as measured on a market value basis—in different types of participating property, 1978—Continued*[1]

Parish	Percentage of tax base			
	Forest	Agric.	Marsh	Total
		percent		
Vermilion	0.16	4.88	0.94	5.98
Vernon	11.37	1.16	....	12.53
Washington	3.85	2.11	....	5.96
Webster	2.50	0.99	0.16	3.65
W. Baton Rouge	1.38	5.44	....	6.82
W. Carroll	0.97	15.91	....	16.88
W. Feliciana	* *	* *	* *	* *
Winn	13.67	0.94	....	14.61
Statewide	1.06	2.05	0.19	3.30

[1] * * Indicates no estimate possible because of the lack of comparable data for the tax years 1977 to 1978.

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Hickman, Clifford A., and Gayer, Peter D. Use valuation of Louisiana's rural lands: Short-run fiscal impacts. Res. Pap. SO–197. New Orleans, LA.; U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1983. 42 p.

The short-run fiscal impacts of switching from market to use assessment for agricultural, horticultural, marsh, and timber lands is explored in this review of Louisiana's 1974 constitutional action.

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Department of
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Forest Service

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Bionomics and Control of the White Oak Borer

J. D. Solomon and D. E. Donley

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SUMMARY

The white oak borer, *Goes tigrinus* (DeGeer), is one of the most serious trunk borers of young trees in the white oak group in the eastern United States. Adult beetles, emerging from late April through May in the South and from mid-May to mid-July in its northern range, oviposit in the cambium through niches chewed in the bark. Newly hatched larvae tunnel directly into the sapwood. Larval galleries in the trunk extend 2 to 6 cm obliquely upward, 8 to 17 cm vertically, and then turn back to the bark surface. Part of a brood develops in 3 years, while the remainder requires 4 years. The borer attacks trees 3 to 55 cm in diameter at breast height (dbh), but prefers stem diameters from 9 to 20 cm. Open-grown trees are favored for attack. Sap-out mortality and woodpecker predation are the major natural controls. Removal of brood trees and managing for non-host species will help minimize losses.

Bionomics and Control of the White Oak Borer

J. D. Solomon and D. E. Donley

INTRODUCTION

The white oak borer (WOB), *Goes tigrinus* (DeGeer), is among the most important insect pests of white oaks in the eastern United States (Baker 1972, Beal *et al.* 1952). As it prefers small trees, this borer is probably the most serious insect borer of trees in the sapling and pole size classes (Solomon and Morris 1965). Donley (1969, 1974) ranked the WOB as the primary pest responsible for defects causing rejection of staves in production of white oak cooperage in Ohio. Except for a popular news article by Solomon and Morris (1965), a recent spatial distribution study in a 1.4 ha white oak stand in Ohio by Donley (1978b), and a few brief notes by other authors, publications on this economic pest are negligible. This paper presents an account of the bionomics, injury, and control of the WOB.

METHODS

The life and seasonal histories of the WOB were studied primarily in bottomland stands of overcup oak, *Quercus lyrata* Walt., in Mississippi and in upland stands of white oak, *Quercus alba* L., in Ohio. Additional studies of presence, host species attacked, and extent of injury, were made in several other eastern states. The major portion of the investigation was conducted from 1972 to 1979.

Collection of insects and their mating, oviposition and host selection behavior have been described elsewhere (Donley 1978a). Distributions were studied in twelve 1/10 ha circular plots located in fully stocked, evenaged stands. The 40-year-old stands were managed for timber and wildlife production. Each *Q. alba* >5 cm dbh was measured and examined for borer attacks.

In Mississippi, 125 sleeve-type cages were installed over attacks on infested trees. Newly emerged beetles were collected from cages 2 to 4 times weekly during late spring and summer to establish the emergence period and to provide adults for study. Mating, feeding, and oviposition habits were studied by confining beetles in sleeve-type screen cages on the lower trunks of saplings. Cages were positioned to enclose living twigs and succulent foliage for a continuous food supply for the adults. Forty-eight fresh egg niches were caged to study the life history. Stem diameter preferred for oviposition was ascertained by measuring 200 infested trees. Stems were cut and dissected to reveal immature stages, feeding and tunneling habits, and parasite infestation. Several hundred additional standing trees were inspected to study portion of tree attacked, signs of infestation, damage, and rate of woodpecker predation.

RESULTS AND DISCUSSION

Stages of Development.—The adult is a large longhorn beetle with a prominent lateral spine on each side of the pronotum (fig. 1). The body is elongate, robust, and cylindrical, ranging from 22 to 30 mm long and 6 to 8 mm wide. It is dark brown with densely mottled white pubescense. The mottling forms indistinct dark elytral bands at the base and near the middle. Females, generally slightly larger than males, have heavier abdomens but slightly shorter antennae.

Eggs are creamy-white, translucent, parchment-like, elongate, and average 4 mm long and 1 mm wide. The larvae are somewhat robust, elongate, and almost cylindrical, but slightly flattened dorsally and ventrally, and slightly broader anteriorly (fig. 2). They are yellowish white with dark brown mandibles and light amber spiracles. The larvae are legless but move upon several well developed ampullae on the abdominal segments; therefore, larval development takes place entirely in its gallery. Larvae are 24 to 32 mm long when mature. Newly transformed pupae are

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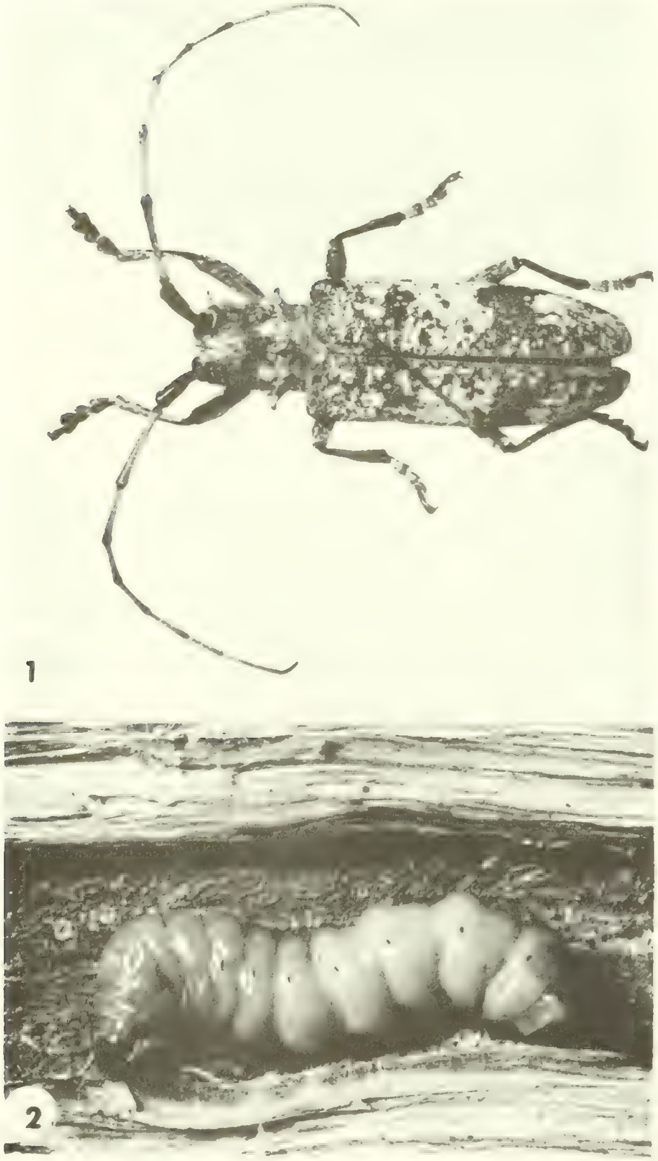
white with a greenish tinge; however, the mandibles, eyes, and appendages darken and become more distinct as adult transformation approaches.

Hosts.—Oak, hickory, and walnut have been recorded as hosts of the WOB (Baker 1972, Beal 1952). The decided preference is for oaks in the white oak group (Beal 1952, Dillon and Dillon 1941, Knull 1946), including white oak, *Q. alba* L.; overcup oak, *Q. lyrata* Walt.; post oak, *Q. stellata* Wangenh.; and swamp chestnut oak, *Q. michauxii* Nutt. It is particularly prevalent in *Q. lyrata* in bottomland forests. Attacks characteristic of *G. tigrinus* were also found in chestnut oak, *Q. prinus* L.

It probably occurs in other oaks of the white oak group, but it is questionable in the red oak group and in hickory, *Carya* spp., and walnut, *Juglans* spp. Although exit holes and bark scars characteristic of *G. tigrinus* have been observed in hickory and black walnut, it seems more likely that attacks in these hosts were due to another borer *G. pulcher* (Hald.). Host preference tests in cages in Ohio including white oak, *Q. alba* L., shagbark hickory, *C. ovata* (Mill.), black walnut, *J. nigra* L., white ash, *Fraxinus americana* L., and red maple, *Acer rubrum* L., support these observations. Seventeen mated females laid 258 eggs—all on *Q. alba*. Three egg niches were prepared on shagbark hickory and one on red maple, but no eggs were deposited. *Q. alba* stems with overlapping bark plates were not used for oviposition although aborted niches were sometimes made through the outer bark layer. Perhaps bark layering restricts oviposition and defines the stem diameter of WOB attack sites and, hence, vertical distribution within stems.



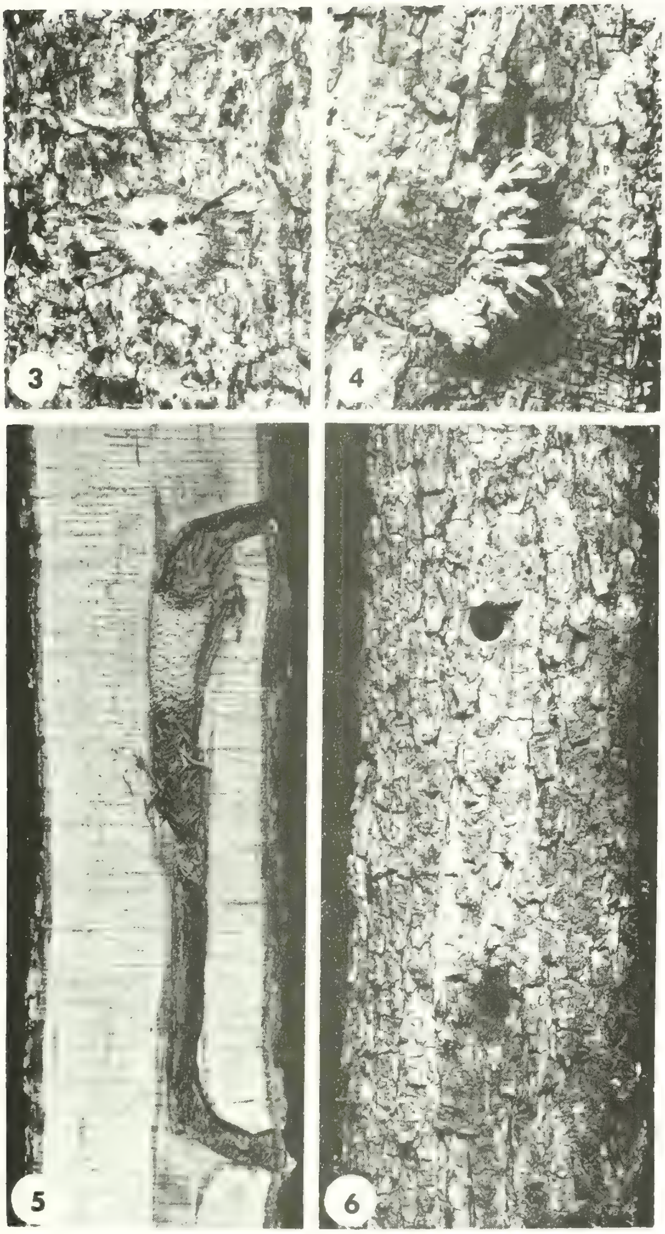
Figures 1-2.—*Stages of* G. tigrinus. *(1) Adult female. (2) Full-grown larva in gallery in overcup oak.*

Distribution.—The WOB has been reported from much of the eastern, central, and southern United States (Beal 1952, Blatchley 1910). Dillon and Dillon (1941) record the insect from 9 eastern states extending from New York south to Florida and west to Louisiana. Gosling and Gosling (1976) list it west to Michigan. In this investigation its injury and collected specimens were observed from Arkansas, Louisiana, Mississippi, Alabama, Georgia, Tennessee, North Carolina, Missouri, Indiana, Ohio, Iowa, and Oklahoma. It has also been reported from Canada (Blatchley 1910) and Mexico (Dillon and Dillon 1941).

Life and Seasonal Histories.—Adult emergence recorded for 88 specimens in Mississippi occurred from April 28 to May 30. Adults, relatively long-lived, have been taken in light traps in Mississippi as late as July 10. In its northern range adults emerge later. In Ohio 114 beetles emerged over a 2-month period from May 17 to July 19. Gosling and Gosling (1976) recorded the presence of adults in Michigan in late July and early August.

Adults fed on twigs and leaf petioles, then mated and females immediately began ovipositing. Eight females paired with males and caged on *Q. lyrata* laid an average of of 9 ± 3 ($\bar{X} \pm SD$) eggs; 17 females caged on *Q. alba* bolts deposited an average of 15 ± 4 eggs. To oviposit, the female chewed an oval niche 5 to 8 mm diam. in the bark, deposited an egg between the bark and wood, and sealed the opening with an accessory gland secretion (fig. 3). Egg niche excavation and oviposition required an average of 21 minutes per egg (182 niches made by 13 females). Although eggs were deposited singly, infested trees commonly had 2 or more egg niches. The largest number of fresh egg niches found on a single tree was 14.

Newly hatched larvae did little or no mining in the phloem or cambium, but tunneled directly into the sapwood. Sap usually oozed from the point of attack



Figures 3-6.—*Habits and signs of infestation of* G. tigrinus *in stems of overcup oak. (3) Egg niche cut in the bark by the female beetle. (4) Ribbon of frass being extruded from gallery entrance indicating an active attack. (5) Sectioned stem showing a typical larval gallery. (6) Elongate hole made by larva below and circular exit hole made by adult above.*

to darken or discolor the surrounding bark. Soon after egg-hatch, tiny strands of fine, moist, yellowish frass were extruded through entrance holes in the bark by 1st and 2nd instar larvae. As the larvae grew, the frass strands became larger, and often assumed the shape of flattened yellow ribbon-like pieces from being forcefully extruded through the vertically elongate entrance holes (fig. 4). Short pieces of shredded wood appeared in the frass during the second year and gradually increased in length. Excelsior-like wood fibers in the frass, 12 to 18 mm long, were an indication of larval maturity and approaching pupation. Yellow frass often accumulated in piles around the base of infested trees.

Larval galleries extended horizontally or obliquely upward in the sapwood for 2 to 6 cm, rose vertically for another 8 to 17 cm, then turned horizontally back to the surface (fig. 5). Adult borers in large stems usually exited the same side of the tree they entered, but on small stems they sometimes exited on the opposite side. Galleries were relatively uniform in shape, but occasionally short diverticula occurred, usually at the junctions of the horizontal and vertical portions of the galleries. Completed galleries ranged from 11 to 23 cm long and 1.0 to 1.5 cm in diameter. A single larva occupied each gallery, but galleries occasionally intersected when populations were heavy.

The mature larva prepared a pupation chamber at the uppermost part of the gallery by plugging it tightly with excelsior-like frass. Pupation in Mississippi occurred during April and early May and lasted 15 to 19 days. The new adult beetle chewed a circular exit hole at the upper end of the pupal chamber directly to the outside and emerged. Thus, each borer left behind two holes, an 8 to 12 mm elongate entrance hole and a 7 to 9 mm perfectly round exit hole (fig. 6). These wounds heal to form characteristic elongate and circular bark scars that remain for many years as evidence of previous infestation.

Forty-eight eggs, marked and caged when deposited, produced 9 adults in 3 years and 7 adults in 4 years for a survival rate of 33 percent. Thus, in Mississippi a generation required 3 and 4 years. Although Donley (1978b) reported a 3- to 4-year life cycle, most researchers mention a 4-year life cycle (Beal 1952, Knull 1946). Baker (1972) mentions 3 to 5 years for a generation. It is likely that a 4- to 5-year life cycle may be more typical of the insect in its northern range.

Distribution of WOB attacks by diameter class and stem height on *Q. alba* in Ohio is summarized in figure 7. Ninety-five of 207 trees were infested with 186 WOBs. Active attacks were found in trees 7.5 to 55 cm dbh. The preferred stem diameter at the point of attack was 10.9 cm; thus, as dbh increased, the height of active attack increased. The average height of attack was 3.4 m. In one 55-cm dbh tree a borer attack was found at 16 m height on a 5-cm diameter branch. The distribution of attacks in *Q. lyrata* in Mississippi was similar to that in *Q. alba*. Eighty-eight percent of 310 active borers occurred in stems 9 to 20 cm in diameter at the point of attack. Borer attacks were observed from ground-line up to a height of 8 m in *Q. lyrata*.

According to Putnam (unpubl. office report) *Q. lyrata*, growing on poor sites of heavy clay soil with poor drainage and prolonged flooding into the growing season, was generally infested with WOB and other borers and had poor quality. High quality stands growing on fertile, silty sites on the edges of active sloughs or on the shelves of bayous had fewer borers. Conversely, Donley (1978b) reported from a study of a 1.4-ha upland stand of *Q. alba* in Ohio that the WOB preferred the fastest growing trees.

Once infested, a tree was often re-infested year after year. Dissection commonly revealed larvae of 2 or 3 ages or broods in the same tree. In one stand, 3 trees had 14, 16, and 24 active attacks. Trees harboring so many attacks should be termed "brood trees" (fig. 8). Young trees suffering repeated attack by WOBs and worked by woodpeckers usually have been invaded by carpenterworms, ants, and decay fungi resulting in many surface scars and rough irregular bark. When trees become heavily damaged and predisposed to carpenterworms, timberworms, and other borers, they offer poor choices for crop trees.

Control.—High populations of WOB typically build up from repeated attacks in a few selected trees within a stand. These brood trees, a reservoir for future infestation and spread to potential crop trees, should be sought-out, identified, and removed during stand management. Donley (1978b) cited an instance in a 1.4-ha stand where 50 percent of the WOBs could have been killed by removing only 14 trees (<5% of the stand basal area). Although brood trees can be spotted at any time of the year and at any time during the life of a stand, they are most easily discerned from spring to fall when the grubs are extruding yellowish frass from the entrance holes.

Natural controls account for some mortality. "Sap-out" caused by oozing, fermenting sap at new egg niche sites kills many newly hatched larvae. Although the effects of sap-out have not been quantified, good growing conditions and adequate rainfall appear to increase the rate of sap-out mortality in bottomland stands of *Q. lyrata*.

Woodpeckers were the most important natural enemy during the 2nd through 4th years of development. Examination of 270 trees infested with 560 WOBs in Mississippi during early spring revealed that 39 percent of the trees had been worked by woodpeckers and 30 percent of the borers had been captured. Predation was most common during the dormant season in infested trees 12 cm or less in diam. and in trees having multiple attacks. We found no parasites of the WOB even though hundreds of attacks were caged and/or dissected. Moreover, none has been reported.

Some localities have a history of heavy damage from WOB, especially *Q. lyrata* growing on poor, frequently flooded sites. Many woodsmen, knowing that certain areas produce timber of poor quality because of borers, and other defects, generally make allowances when selling, buying, and/or managing these

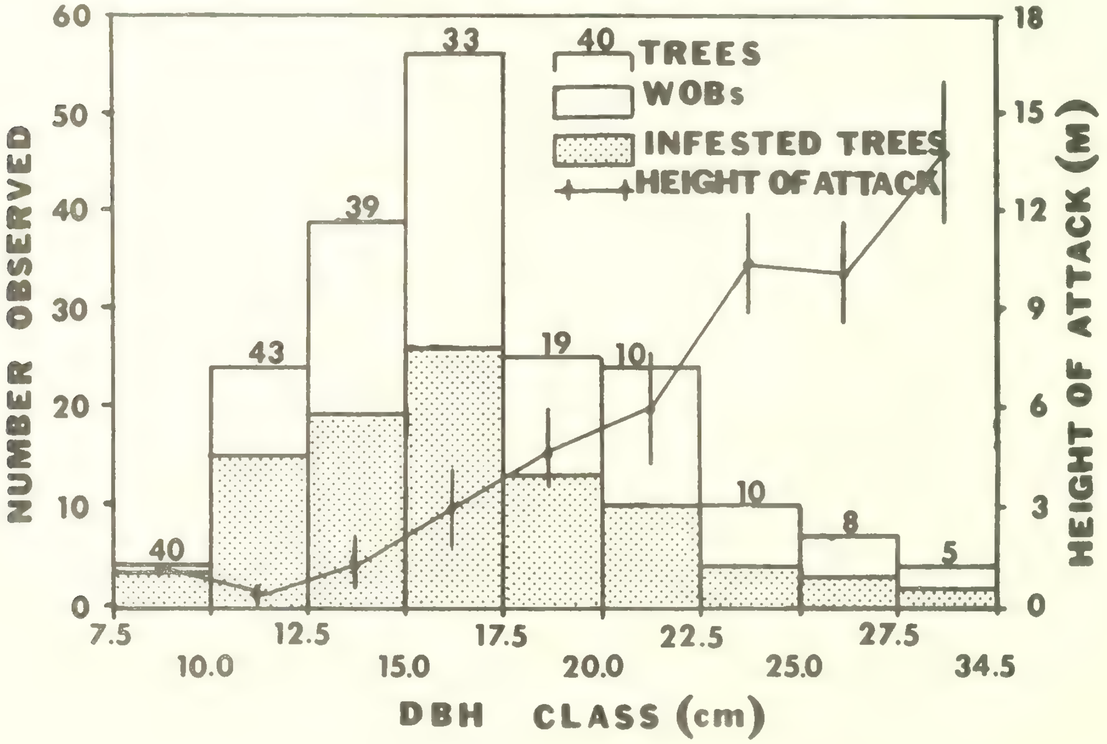


Figure 7.—*Distribution of* G. tigrinus *attacks by diameter class and stem height (X ± SD) on* Q. alba *in Ohio.*

stands. Integrating information on borer behavior into stand management of poor sites would lead managers to favor other tree species in harvest, cull, or improvement cuts.

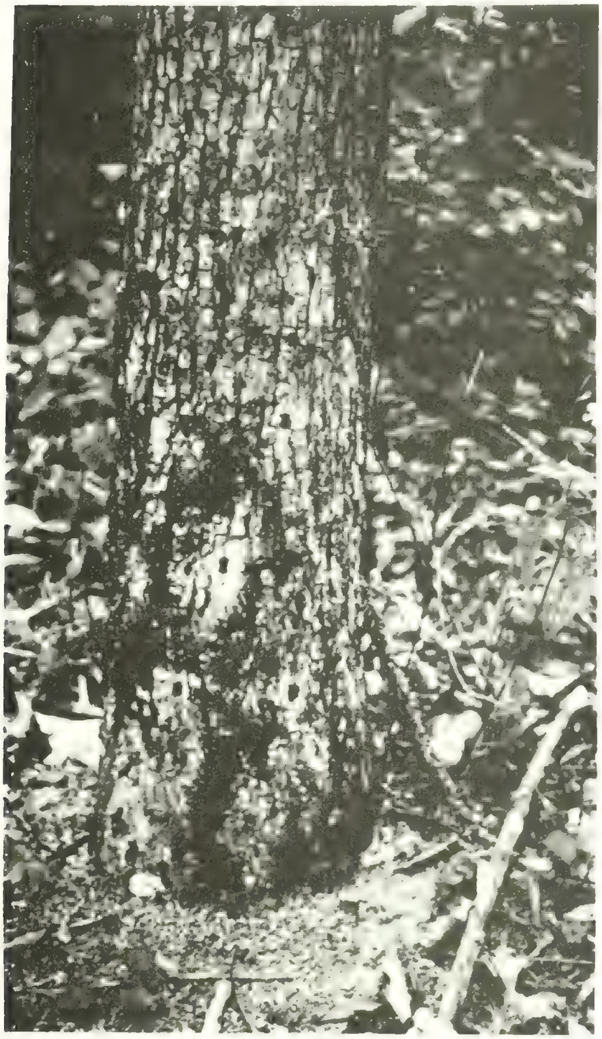


Figure 8.—*Brood tree of overcup oak with numerous* G. tigrinus *holes in the lower trunk and frass piled around the base of the tree.*

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Solomon, J. D.; Donley, D. E. Bionomics and control of the white oak borer. Res. Pap. SO-198. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1983. 5 p.

Bionomics, injury, and control of one of the most destructive trunk borers of young trees in the white oak group.

Keywords: *Goes tigrinus,* Cerambycidae, *Quercus* pest, product defects.

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Microhistological Techniques for Food Habits Analyses

Mark K. Johnson, Helen Wofford and Henry A. Pearson

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Microhistological Techniques for Food Habits Analyses

Mark K. Johnson, Helen Wofford and Henry A. Pearson

INTRODUCTION

The use of micro-anatomical features for identification of plants in diets of herbivores has received wide application since the early reports of Baumgartner and Martin (1939), Norris (1943), and Dusi (1949). However, detailed descriptions of specific techniques have not been fully reported. Those attempting to learn how to quantify diets microhistologically have great difficulty without help from experienced technicians.

The purpose here is to describe specific techniques used to prepare and quantify herbivore diet samples for microhistological analyses. It is beyond our scope to provide a detailed taxonomy based on micro-anatomy. However, the variety of plants described here represents probable numbers and anatomical variations that may be normally expected in a diet study. Additional variations of micro-anatomical features exist in other plants. The reader should refer to Metcalfe (1960) for a complete description of plant micro-anatomy. Here we describe the types of anatomical structures useful for identifying plant fragments regardless of the variation in each.

We thank R. M. Hansen, Colorado State University, L. J. Korschgen, Missouri Department of Conservation, J. L. Holeckek, New Mexico State University, and J. E. Moore, University of Florida, for reviewing early drafts. This project was supported by the U.S. Forest Service and Mississippi State University under cooperative agreement No. 19-335.

REFERENCE MATERIALS

The plants described in this report are a select group of those common on longleaf-slash pine-bluestem range of the lower coastal plain in the southeastern United States. Plant names used in this paper follow those provided in the National List of Scientific Plant Names (USDA, SCS 1982).

Some researchers prepare reference and study materials by carefully scraping away tissues to expose the cutinized epidermis on the opposite side (Korschgen 1977). This method is preferable to ripping tissues in a blender when intact leaves are needed for taxonomic description. However, for diet analysis reference materials must simulate the small fragments found in samples following mastication and digestion. Therefore, we prepared reference plants by mixing about 1 g of dry leaves and 20 ml of liquid household bleach at high speeds in a blender.

Hertwig's solution can be used to clear pigments from plant tissues (Cavender and Hansen 1970, Flinders and Hansen 1972, Todd and Hansen 1973). However, soaking samples in household bleach accomplishes the same thing with greater ease (Reynolds et al. 1978).

Some researchers stained plant specimens after decolorizing (Dusi 1949, Voth 1968, Field 1972, Fitzgerald 1976). Although staining aids in distinguishing certain features, some do not stain materials (Stewart 1967, Cavender and Hansen 1970, Hansen 1971, Westoby et al. 1976, Johnson 1979), and we believe it unnecessary.

We used Hoyer's solution for making permanent slides. However, this solution is hygroscopic so that in warm, humid climates slides become sticky and must be stored in low humidity environments for months before they are dry. An alternative plastic mounting medium can be made with lactic acid, phenol crystals, and polyvinyl alcohol. The plastic medium dries within a few days. (Directions for preparing both Hoyer's solution and the plastic medium are in Appendix I).

When permanent slides are not needed, plant fragments can be mounted in a solution of soapy water or water mixed with a small amount of gum arabic. Water infiltrates the tissues quickly and slides can be examined immediately.

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PREPARATION OF DIET SAMPLES

Diet samples come from esophageal or rumen fistulated animals, stomachs, rumens, intestines or ceca of dead animals, or fecal droppings. The condition of fragments in esophageal samples is similar to reference material making sample preparation relatively easy. Digested fragments are more difficult to identify since the number of anatomical features per fragment is less usually. Fecal materials exposed to the environment for long periods may be difficult to identify, but decomposition in arid environments may be so slow that fossil dung more than 10,000 years old has been used to obtain a record of an animal's diet (Hansen 1978).

Whenever stomach or rumen samples are available, gross examination with dissecting equipment at low magnifications is recommended before grinding for micro-analysis. Some foods do not have distinctive micro-anatomical characteristics and can only be identified before digestion. On the other hand the presence of some plants can be easily detected by micro-analysis while they may not be detected by gross examination (Yarrow 1979).

DIAGNOSTIC FEATURES

Leaf fragments in diet samples are identified by comparison with fragments and drawings made from reference slides. Drawings can be made by hand or with the aid of a drawing tube attached to a microscope. This piece of equipment allows non-artists to accurately outline the micro-anatomy of plant fragments but all structures do not lie on the same plane so that drawings can not perfectly represent the appearance of fragments in a microscope (Appendix II). Descriptions of plant micro-anatomy from Metcalfe (1960) were used to guide our study of those structures most useful for identification. We generally ignored Metcalfe's descriptions of relative abundance for certain structures since these characteristics are only apparent on large leaf fragments. Therefore, our descriptions are limited to micro-anatomical variations of certain structures.

Micro-anatomy of Monocots

The parallel veins of grasses readily separates leaf tissue into zones, and clearly distinguishes grass leaf fragments from those of dicots. While identifiable tissues from sheath, flower, seed, or culm are often present, leaf blades provide the most useful tissue for microscopic identification of the grasses (Metcalfe 1960). Minor anatomical differences appear on the same leaf, among leaves of the same plant and among different plants. However, micro-anatomical characteristics have been used for taxonomic differentiation of species, genera, and families (Davies 1959, Tateoka 1957, and Metcalfe 1960).

Costal Girder and Bulliform Cells.—The areas directly over and around the veins are termed costal zones while areas between the veins are termed intercostal zones (Metcalfe 1960). Schlerenchymous cells called costal girders surround the veins and are common to grasses from dry habitats (Metcalfe 1960). Bulliform cells are located intercostally and have thinner cell walls than costal girders. They are large, highly-vaculated, epidermal cells. Their function is not known but sometimes they are filled with silica (Esau 1965). Since the arrangement and appearance of costal girder cells are highly variable, we have not found costal girder and bulliform cells to be useful features for identification of grasses.

Long and Short Cells.—There are two other distinct cell types (long and short) in typical epidermis. Long cells are very narrow and run parallel to the vascular bundles. They are a major constituent of the intercostal zone but may also be found over the costal zone. Cell walls may be sinuous or non-sinuous with varying degrees of each (fig. 1). Long cells surround short cells and stomata (Esau 1965). We found that length and width of long cells provide some clues as to the identity of a fragment, but the nature of the cell walls is the primary characteristic we compare with reference materials when trying to identify leaf fragments.

Short cells are dispersed among the long cells and may appear over the costal zones. They are filled with silica or cork. We have found the shapes and sizes of silica cells in the costal areas to be particularly diagnostic.

Metcalfe and Chalk (1950) classified about 20 different shapes of silica cells. Three main shapes we

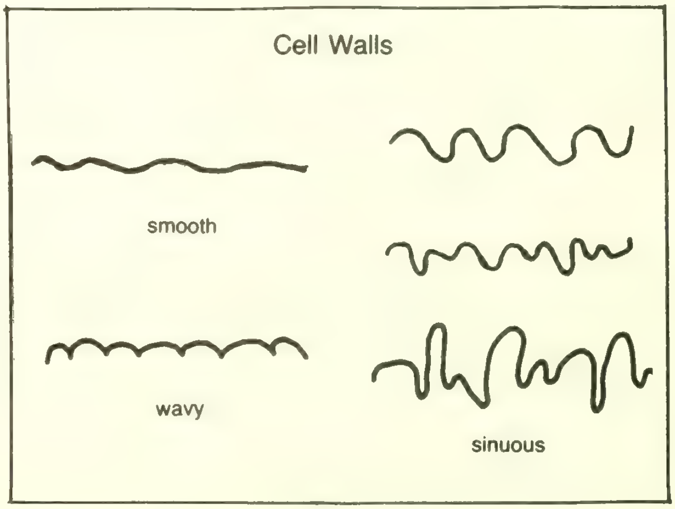

Figure 1.—*Variations in cell walls of grasses.*

have found are dumbbell, non-dumbbell, and dumbbell variations. Non-dumbbell shaped silica cells are square, cuboid, or irregular cuboid (fig. 2). For dumbbell shaped cells in the costal region, length, width, and angular characteristics of the middle and ends aid in identification of species (fig. 3).

For silica cells in the intercostal region, shape and abundance differ among species. They often occur in pairs called companions or couples (fig. 4). Comparison of silica cell size is often useful for distinguishing among species where shapes are similar. However, when size is used for identification a number of different fragments must be examined to account for variation. Size is most useful for distinguishing between genera rather than species. For example, the shape of silica cells found in leaves of *Andropogon*, *Schizachyrium* and *Panicum* is bone-like but those in *Panicum* leaves are generally smaller.

Stomata.—Stomata of grasses occur intercostally. Openings are surrounded by guard cells that are narrow in the middle and bulbous on the ends. In addition, stomata of grasses are accompanied on their parallel axes by two subsidiary cells (Metcalfe 1960).

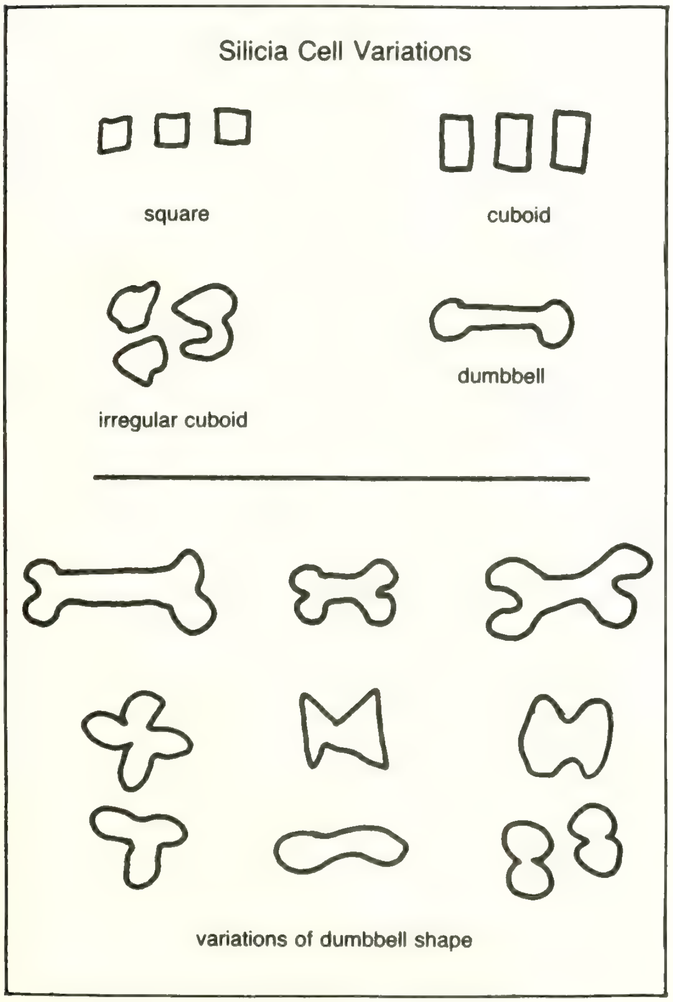

Figure 2.—*Variations in shapes of silica cells observed in grasses.*

It is easier to identify grass species whenever both stomata and silica bodies are present on the same fragment. The size of stomata is not useful for identification except where they are extremely small or large.

Trichomes.—Four types of grass trichomes are useful for identification. They are macrohairs, microhairs, prickle hairs, and papillae (fig. 5). Macrohairs are visible with the naked eye or hand lens. Some are multicellular but the shape of the proximal end is the most outstanding feature. Of all the hair types, microhairs are the least diagnostic because in diet samples the distal cell of bicellular microhairs is often broken, leaving a blunt end (Metcalfe 1960).

Prickle hairs are very common but there are few differences in their appearance among species. Usually located on margins, veins, or between long cells, they simply aid identification by lending a characteristic appearance to fragments. By contrast, prickle hairs vary in shape, location and distribution on leaves so that they may be very useful for taxonomic characterization of species when complete leaves rather than small fragments are examined.

Papillae are protrusions of the epidermal surface which take a variety of shapes. We found that sedges (*Carex* spp.) and pineywoods dropseed (*Sporobolus junceus*) had numerous papillae present.

Micro-anatomy of Dicots

Trichomes.—Trichomes provided a primary means for identifying dicots since they differ more among species than other epidermal cells, crystals or sto-

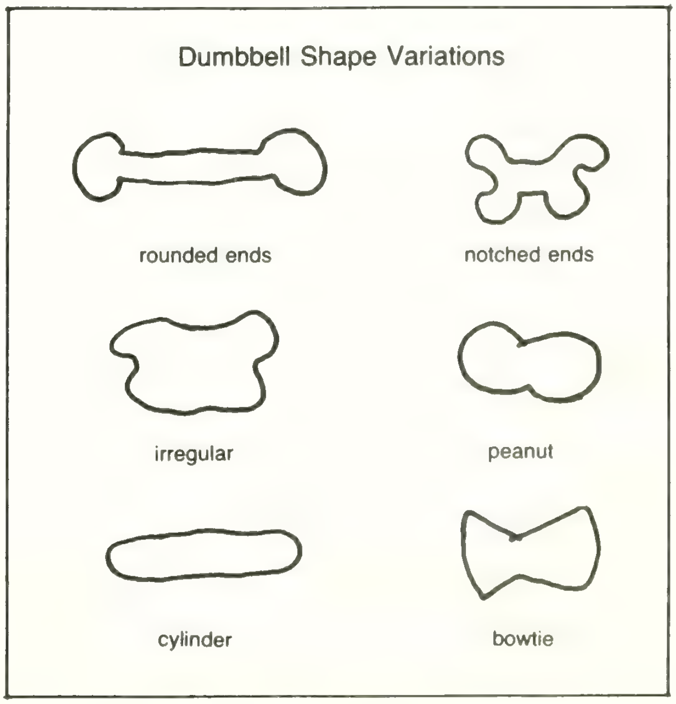

Figure 3.—*Variations in shapes of dumbbell shaped silica cells observed in grasses.*

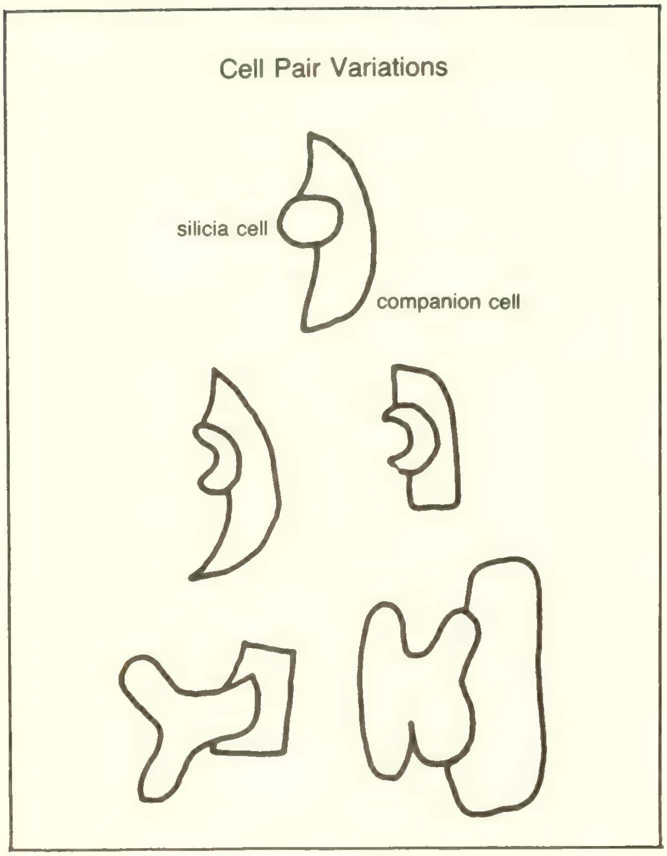

Figure 4.—*Variations in the appearance of silica cell pairs which occur in grasses.*

mata. Metcalfe and Chalk (1950) classified families into those having glandular or nonglandular trichomes and also according to the numbers of component cells. Trichome anatomy has been used for generic classification by Rollins (1944), Heintzelman and Howard (1948), Cowan (1950), and Hummel and Staesche (1962). While the shape of plant hairs differs among some taxonomic divisions, there is often considerable uniformity within genera.

We found shape and number of cells making up a trichome to be the best starting point for identifying dicot species. We observed 4 basic kinds of trichomes: ligulate, branched, compound and papillate (fig. 6). Characteristics such as size of the base, shape of the apex, texture of the surface and degree of tapering are useful for identification (fig. 7).

Epidermal Cells.—Unless otherwise indicated, epidermal cell as used here refers only to epidermis of leaves including cells of the upper leaf surface, lower leaf surface, trichome attachment cells, and specialized cells such as glands. Shapes of epidermal cells vary among families, genera, species, and parts of the same plant. Their form is affected by factors such as light intensity and atmospheric humidity. Thus, the size, shape, and walls of epidermal cells may vary from year to year and place to place (Metcalfe and Chalk 1950). In addition, some plants have multiple epidermal layers (Esau 1965).

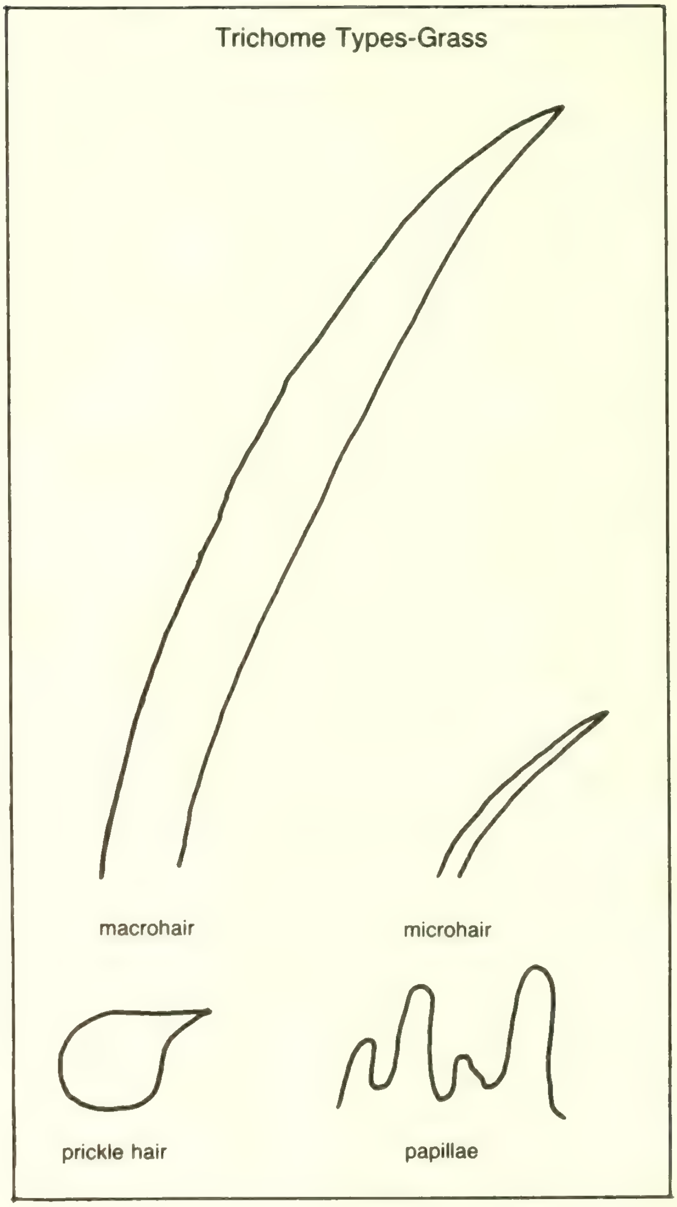

Figure 5.—*Four basic shapes of trichomes commonly found on grass leaves.*

Despite variation, characteristics of epidermal cells are highly useful for plant fragment identification. Notable features include wall structure, relative size, and relative thickness. Two distinct shapes are angular and contour. Angular cells have pointed or rounded corners, and five, six, or eight straight sides which give the tissue a honeycomb appearance. By comparison, the walls of contour cells fit together like those of a jigsaw puzzle. We found the degree of contour in the walls to be characteristic (fig. 8).

Trichome attachments have different shapes than other epidermal cells, and there is usually a constant number of cells surrounding each attachment (fig. 9). Glands occur on epidermal tissues of many plants and are usually smaller than other trichomes (fig. 10).

Crystals.—Crystals are formed from secretions of calcium carbonate, calcium oxalate, starch, or silica. While leaves of *Rubus* contain large crystals called druses, those produced by *Lonicera* are usually larger and fewer. Crystals are located in epidermis, vascular tissue, and stemlike tissues around trichome attachment cells. Types of crystals are druses (starshaped), raphides (needlelike), various square or rectangular crystals, and intermediates of druses and squares (fig. 11).

Stomata and Companion Cells.—Stomata are usually most abundant on the lower surface of leaves. However, they may also be located on upper surfaces or on the epidermis of petioles, stems and flowers. The companion cells that surround the guard cells are not generally useful for identification. Exceptions are those that appear to have corner cells at the point where two guard cells meet. These tiny triangular cells are common to *Quercus*, but they are also found in most conifers and ferns.

Frequency and size of stomata are highly variable characteristics that depend on environment, geography, and location on the plant. These characteristics are not useful for identifying small fragments. More useful for identification is the number of epidermal cells that surround stomata. Among the plants in our collections are the patterns outlined by Metcalfe and Chalk (1950): irregular-celled (four or more cells surround the stomata), three unequal-celled (three cells surround stomata, one may be distinctly smaller than the other two), parallel-celled (two cells surround

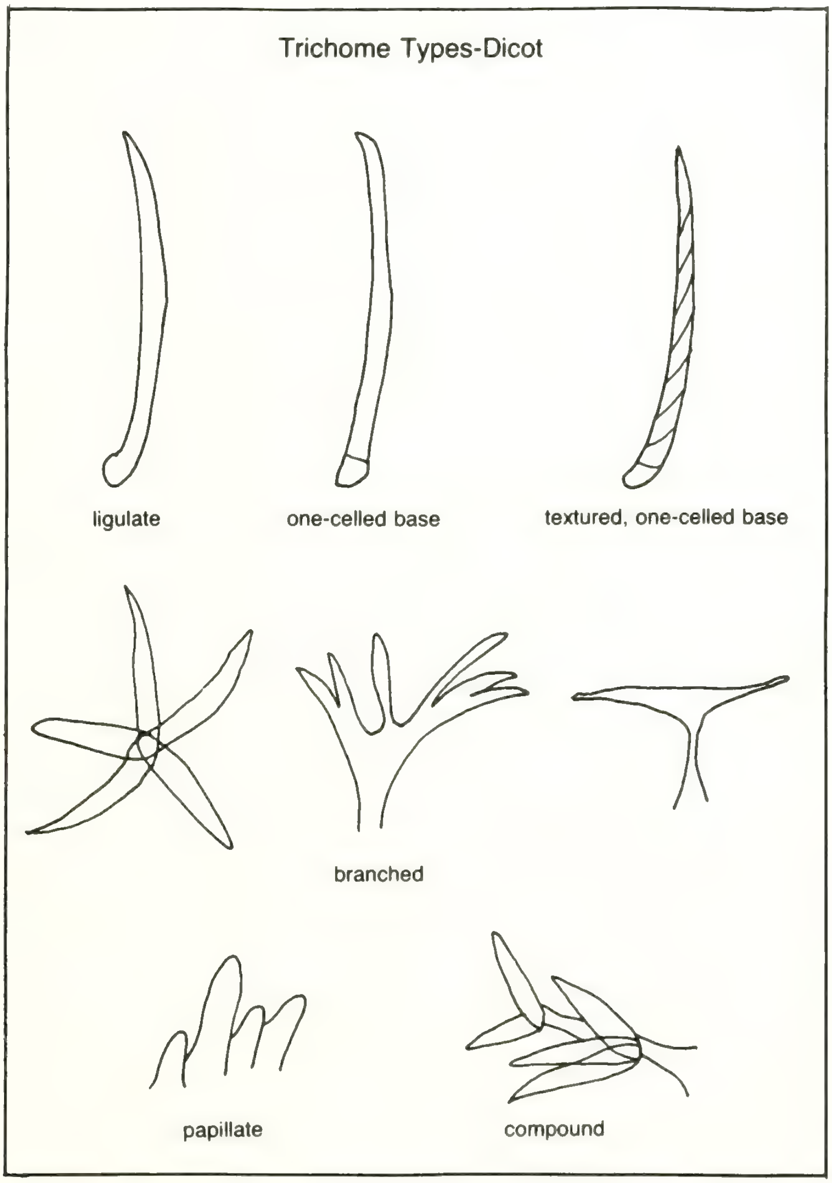

Figure 6.—*Basic kinds of trichomes commonly found on leaves of dicots.*

stomata and their common side is parallel to the long axis of the pore), and cross-celled (two cells surround the stomata and their common wall is at right angles to the long axis of the pore)(fig. 12).

IDENTIFICATION

Whether plant fragments are from reference material or diet samples, they are not uniform in size, shape, or thickness. We mount samples on glass slides (3″ × 1″; cover slips, 20 × 40 mm) in a layer of medium about 1.0 mm thick. All of the fragments do not lie in the same plane, and some individual fragments curl so different anatomical structures do not lie on the same plane of focus. In addition, tissue thickness causes anatomical structures to be on different planes of focus. Complete view of a fragment requires focusing through tissues until all features are examined. Composite drawings such as those published here do not represent the true appearance of fragments under a microscope, and the necessity of focusing through tissues limits the use of photomicrographs for illustration or as reference material. However, after study, drawings provide excellent reference with reduced effort compared to constant exami-

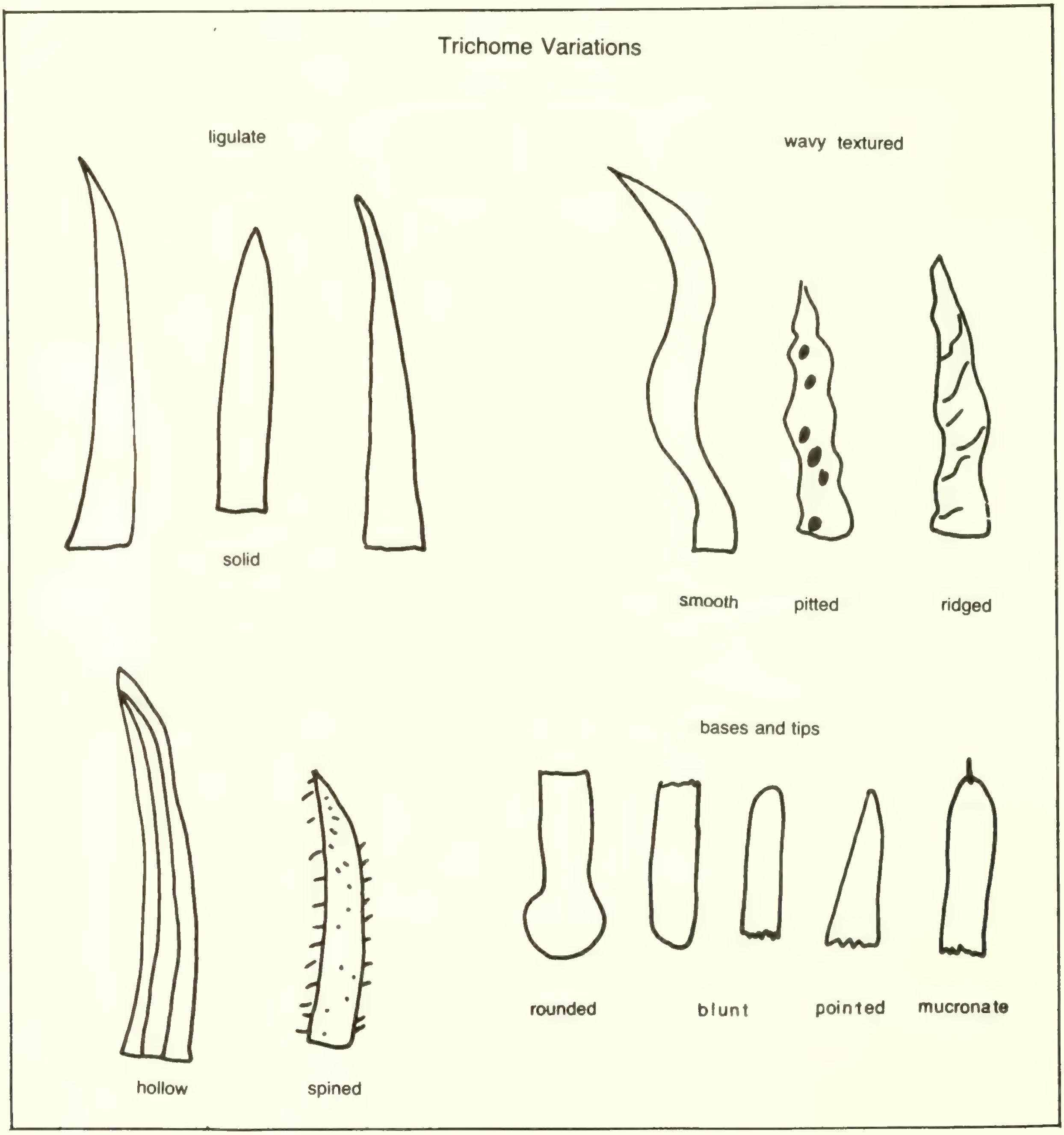

Figure 7.—*Basic characteristics of tips and bases of trichomes usually found on leaves of dicots.*

nation of reference slides which are only needed for confirming uncertain identifications.

Distinguishing monocots from dicots is simple because of the pronounced difference in venation. However, distinguishing among different dicots requires recognition of cell patterns and anatomical structures. Often the presence of a distinctive trichome is sufficient evidence for identifying a fragment. However, some trichomes separate from fragments and in these cases accurate quantification requires association of trichomes with epidermal fragments. For species or parts of leaves without distinctive trichomes, identification depends upon study of cell shape, characteristics of cell walls, the form of stomates, and the presence of crystals. Usually, only one or two micro-anatomical features are needed for identification of dicots.

Identification of grasses, requires study of the cell walls, stomates, and silica cells. In general, fragments of different grasses appear more similar to each other than fragments of dicots. When a sample contains two or more grasses, fragment identification usually requires the presence of at least two distinctive features.

For a large collection of species, it would be difficult to identify plants without large pieces of leaves so that a complete pattern of structures could be examined compared to what can be seen on small fragments. However, practical food habits studies deal with a limited list of plants from which herbivores usually select a few staples during any season. By the process of elimination and intense study of reference plants, small fragments of leaves can be used to identify the foods selected by a herbivore.

QUANTIFICATION

Anthony and Smith (1974) visually estimated the contribution of each species to the numbers of fragments observed on microscope slides. Although this method seems efficient and practical, there is no control over observer bias. Most quantification of plant fragments identified on a microscope slide has been performed by counting fragments or by using some variation of simple counting. Voth (1968) measured the dimensions of each fragment to calculate an area

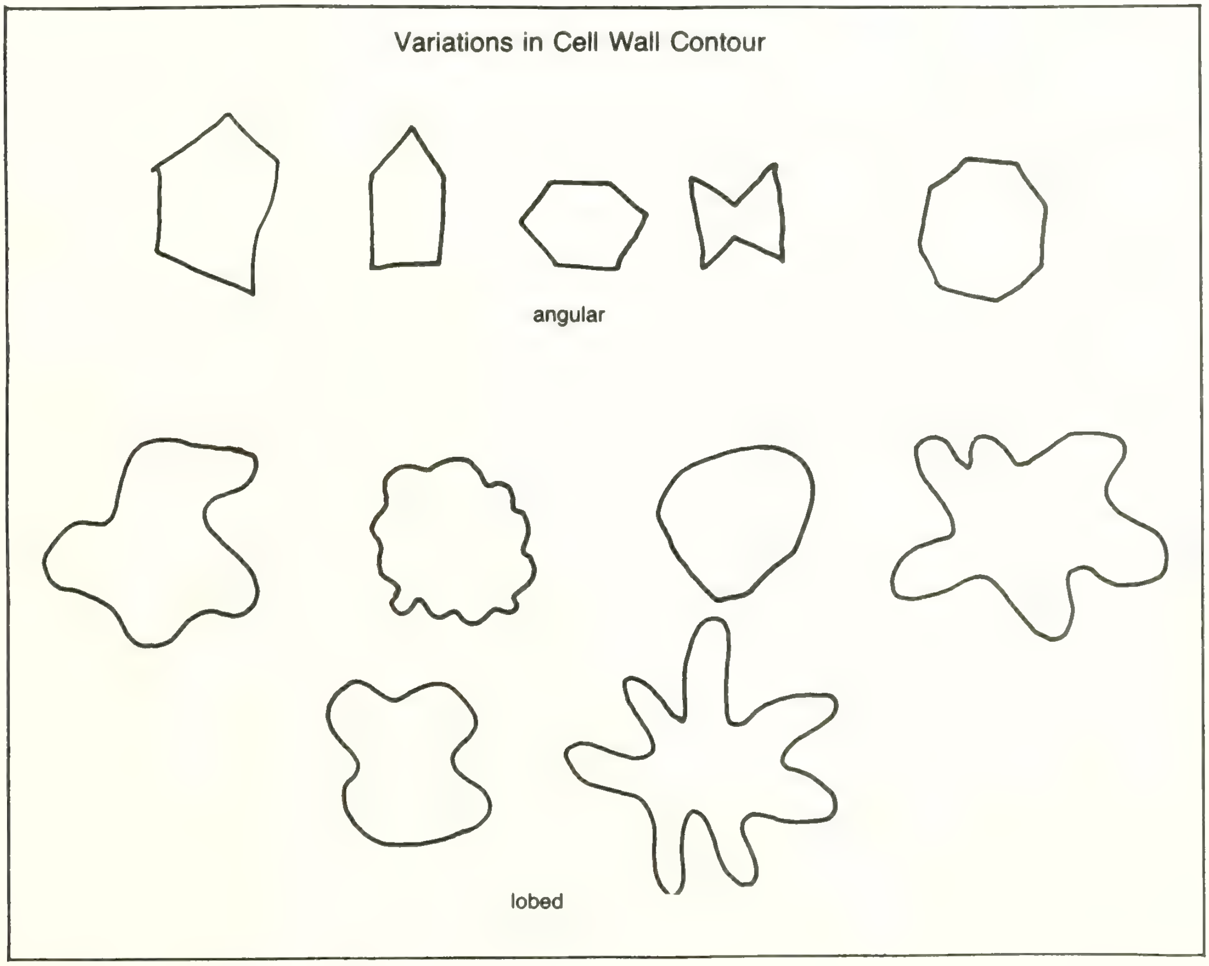

Figure 8.—*Variations in the contour of cell walls in leaves of dicots.*

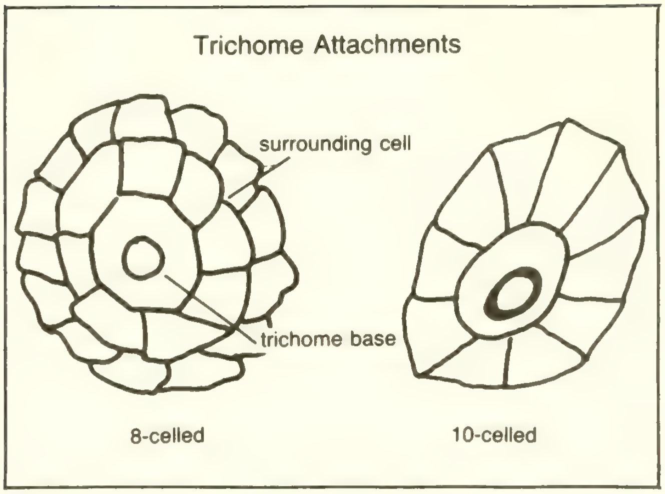

Figure 9.—*Examples of trichome attachments observed on leaves of dicots.*

for each one. Other researchers have counted the numbers of fragments and calculated the relative number for each species (Storr 1961, Ward and Keith 1962, Myers and Vaughan 1964, Bear and Hansen 1966, Sparks 1967, Stewart 1967).

Frequency Sampling

Frequency sampling is nothing more than recording the presence or absence of an item in a sampling unit. The method has been employed for study of wild plant distributions and abundance (Fracker and Brischle 1944), and relative abundance of wild animals (Caughley 1977). Sparks and Malechek (1968) demonstrated that frequency sampling was an accurate alternative to counting each plant fragment when quantifying botanical compositions on microscope slides. As a result the procedure has been used for estimating herbivore diets by a variety of researchers (Flinders and Hansen 1972, Todd and Hansen 1973, Hansen et al. 1973, Dearden et al. 1975, Johnson 1979).

The technique is relatively simple. Microscope slides are made with mixtures of plant fragments ground in a Wiley Mill over a 1.0 mm mesh sieve so that all particles average about the same size. A predetermined number of fields are systematically examined at the same magnification, and the presence of each species is recorded.

Frequency of occurrence is calculated for each species. As long as the amount of ground plant material on each slide is relatively small (1 – 3 fragments per field), average relative frequency of occurrence represents average relative abundance of the different species in the mixture. Since bulk densities of leaves from different plants are about equal, relative abundance provides an estimate of relative dry weight for each food in a herbivore's diet (Johnson 1982). A number of published reports demonstrate that, in general, this technique provides accurate estimates of herbivore diets whether study materials are stomach contents or fecal pellets (Hansen et al. 1973, Dearden et al. 1975).

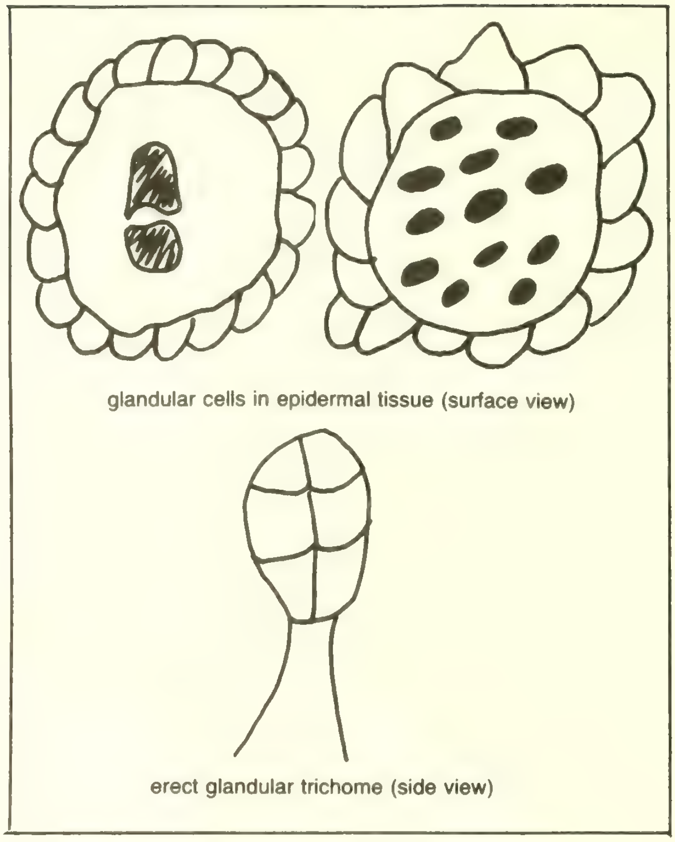
glandular cells in epidermal tissue (surface view)
erect glandular trichome (side view)

Figure 10.—*Examples of glands observed on leaves of dicots.*

Under the following assumptions each microscope field is treated as a sampling unit: (1) microfragments of plants are randomly distributed on microscope slides, (2) microfragments from different plant taxa are the same average size, (3) dry weight bulk densities of different plant taxa are the same. These assumptions are valid since the distribution, size and average number of fragments per microscope field is controlled in slide making and since there are no significant differences in dry weight bulk densities among the leaf tissues from different plants.

The relationship between particle density and frequency of occurrence is based on finite numbers of plant fragments distributed at random over a microscope slide. A detailed description of the mathematical theory is available in Johnson (1982).

The standard form of the realtionship between frequency and density is

$$F = 1 - e^{-d}, \tag{1}$$

where F is relative frequency, e is the natural logarithm and d is the mean particle density determined by the number of fragments (n) and number of microscope fields examined (k) so that

$$d = {}^{n}/_{k}. \qquad (2)$$

If fragments from m different plant species are randomly distributed in the microscope fields, the particle density (average number of fragments per field) of each is independent from the others. Relative particle densities (r_i), which are estimates for the relative dry weights of each plant in the diet sample, can be calculated:

$$r_i = \frac{d_i}{\sum_{i=1}^{m} d_i}, \qquad (3)$$

where $i = 1, \ldots, m$ and d_i's are the particle densities for each species. For example, we may simultaneously count the presence or absence of several different taxa in a microscope analysis. Since proper mixing and spreading of microfragments assures randomness and independence of particle distributions, separate estimates for each taxon's particle density may be obtained and relative particle densities calculated.

In practical applications one seeks to estimate the average particle density, which is unknown and not easily estimated. This is done by estimating frequency of occurrence, which is also unknown but easily estimated by recording particle presence or absence, and then estimating density from frequency using equation (1). Estimates for frequency of occurrence are subject to sampling variability.

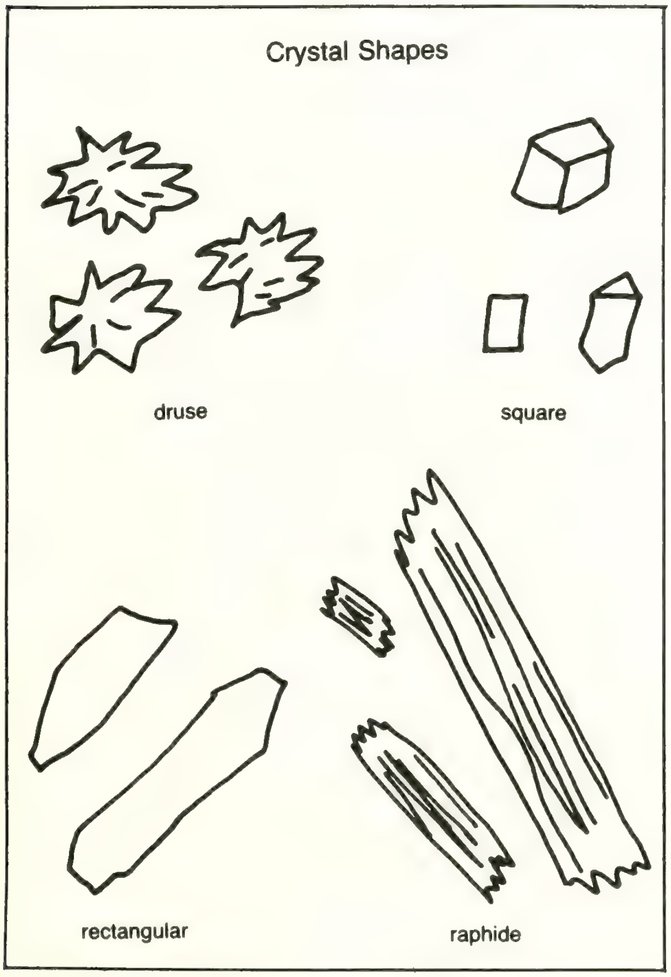

Figure 11.—*Basic examples of crystals observed in leaves of dicots.*

Relative precision of the estimate for density is also dependent on average frequency (Curtis and McIntosh 1950). As average frequency increases, relative precision increases up to an optimum. Precision decreases for larger particle densities because most or all of the fields contain at least one identifiable plant fragment. This result imposes constraints on the maximum particle density which is allowable on microscope slides. Conversley, low particle densities of rare taxa, which result when microscope slides are made to avoid high particle densities for abundant taxa, require intensive sampling to yield precise estimates of these particle densities. We obtain accurate results in quantifying mixtures when slides are made so that microscope fields contain from 3-5 identifiable fragments.

Relative Discernability and Digestion

Since all fragments can not be identified, there have been attempts to account for differences among species as to proportions of fragments that can be

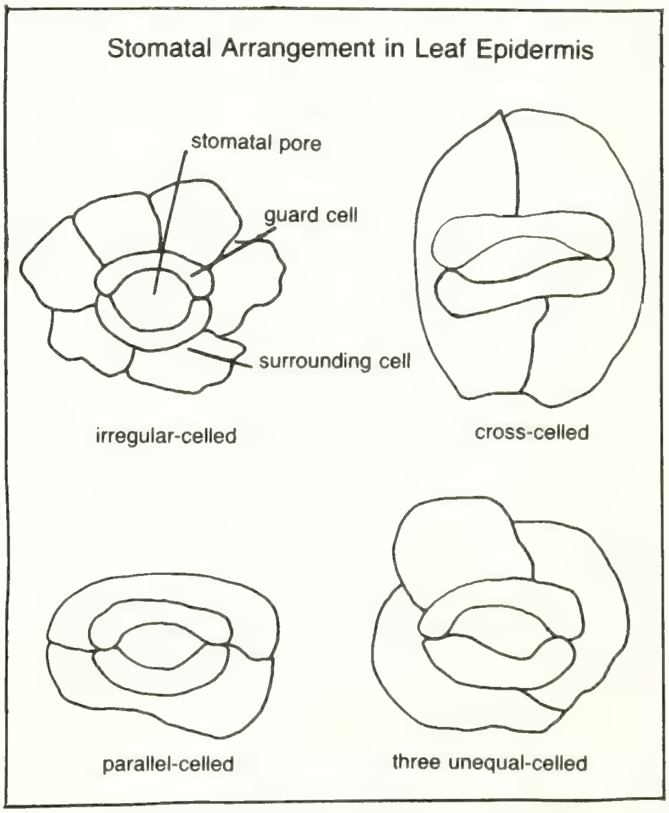

Figure 12.—*Basic arrangements of stomata and surrounding epidermal cells observed in leaves of dicots.*

identified, and to account for the affects of digestion on the discernability of fragments. In addition, for the same weight of leaf material some plants fragment during mastication or sample preparation into more than twice the number of pieces as other plants (Johnson et al. 1983).

Differential digestibility has been widely discussed as introducing bias into diet estimates when fecal samples are used. Some researchers have gone to great lengths to adjust data to account for effects of digestion (Voth and Black 1973) even though reports were not available to suggest that digestion significantly biased analyses. There are no known microorganisms that possess cutin degrading enzymes (Frey-Wyssling and Muhlentahler 1959). The equivalence factors reported by Voth and Black (1973) were related to digestion of tissues underlying the cuticle rather than reduction of the cuticle. Plant fragment identification is based on micro-anatomical characteristics of an indigestible cuticle and cells underlying the cuticle that escape digestion. Leaves are made of epidermis, mesophyll, and vascular bundles. Epidermis is covered by indigestible cuticle which inhibits digestion of mesophyll by blocking passage of microbes into the leaves (Harbers et al. 1981). However, once passage is gained by maceration, mesophyll is readily degraded while epidermis and cells surrounding vascular bundles are degraded next (Aiken 1979). Generally, lignified vascular tissues resist digestion. Theoretically, identification is made only from cutin which retains the impression of epidermal tissues. But undigested groups of cells enhance the visibility of cutinized fragments because the increased thickness causes greater refraction of light. Microhistological identification is easier when both the epidermis and underlying tissues are present.

We recorded numbers of fragments and proportions identifiable for a variety of undigested and digested plants (Johnson et al. 1983). For 47 species tested, digestion increased discernability for 3 and decreased discernability for 9 by more than 10 percent while the other 35 plants were little affected.

Digestion improved discernability for plants having highly suberized, pigmented cell walls, and few trichomes by clearing pigments from tissues making cells easier to see. Digestion decreased discernability for plants having thin cell walls and few stomates or trichomes. Easily identified plant fragments generally had an abundance of features that were easily recognized. Regardless of these affects, we found that they were not dramatic enough to have very much influence on estimates of botanical composition (Johnson et al. 1983). This work helped to explain why estimates of botanical compositions for feeds and feces have usually been significantly similar (Todd and Hansen 1973, Hansen et al. 1973, Johnson and Pearson 1981.)

WOOD FIBERS, MUSHROOMS AND MAST

Wood Fibers

Digesta from animals that browse or gnaw wood may contain fragments that cannot be identified by gross analysis. However, wood fibers can be identified microscopically and often occur in slides made from fecal materials. Identification is performed by comparison with reference materials in the same manner as leaf fragments are identified.

Preparation of reference fibers or wood fragments taken from food habits samples is performed by maceration in a 50:50 mixture of glacial acetic and 30% hydrogen peroxide. Wood fragments should be refluxed in the solution for 1 to 2 hours. The specific time needed should be established through practice; some wood will take longer than others. Variations on this procedure are also available (Panshin and deZeeuw 1980). Materials should be rinsed thoroughly after maceration. Microscope slides can be made and examinations performed as they are for other plant fragments.

Diagnostic features are size, shape, and pitting of fibers. Tracheids are the only cells useful for identification of softwoods. Various features of vessel elements and tracheids as well as the presence or absence of tracheids are diagnostic for hardwoods (Carpenter and Leney 1952, Panshin and deZeeuw 1980).

We know of no authors employing these procedures in food habits studies. We have observed the fibers in fecal pellets of a variety of herbivores but have never attempted quantifying them.

Mushrooms

Herbivores, as well as other animals, eat mushrooms, and proportions in the diet may be significant. Many animals consume mushrooms that are poisonous to humans. Mushrooms tend to concentrate phosphorous and are rich in protein (Miller and Halls 1969, Fogel and Trappe 1978). Both of these nutrients may be lacking in the vegetation of some regions.

The presence of mushrooms in food habits samples complicates quantification. The point analysis method useful for quantifying relative dry weights of macroscopic fragments in stomachs has two requirements; bulk densities of materials should not differ greatly and the form of different items must be similar (Chamrad and Box 1964). For example, the dimensionless quality of point methods is destroyed if large flat pieces of leaves are analyzed in mixtures with small seeds which have a much higher bulk density but a lower probability of occurrence at a point.

These problems can be overcome by hand separation of mushrooms for separate weighing or volumetric study, or by microscopic analyses of ground samples. Regression equations can be developed to relate occurrences of mycelia in stomachs to occurrences of plant fragments.

Digestibility of fungal mycelia is nearly complete except where large amounts are ingested in a single meal. We have observed intact mycelia in feces in these cases. However, when mushrooms are eaten in smaller amounts, only spores are present in fecal material. Although indigestible (Fogel and Trappe 1978), spores may not be detected in fecal samples during routine analysis because they are generally tiny. Some can be detected at 100 magnifications but others require 500 to 1000 magnifications before they can be seen.

Proportions of fecal samples made up by spores might be large for small, mycophagous mammals (Tevis 1952), but insignificant for other wildlife; while the proportion of the diet they represent can be more than 30% (unpublished data). Therefore, accurate diet quantification requires developing correlations between amounts eaten and number of spores.

To demonstrate this procedure we separately ground dry mushrooms (*Amantia* sp.) and plant leaves in a Wiley mill through a 20 mesh sieve. Microscope slides were prepared with 14 different amounts of pure plant fragments ranging from 6 – 60 mg. Ten slides were made for each different weight so that 140 slides were used. Slides were also made with 8 different amounts of pure ground mushrooms ranging from 1 – 40 mg and 10 replications were made so that 80 slides were used. We then counted the number of plant fragments (125 ×) (regardless of whether they were discernable fragments) (fig. 13) and the number of spores (500 ×) in each microscope field (fig. 14). Twenty fields were examined for each slide, averages were calculated and grand averages were calculated among the slides for each different weight of material.

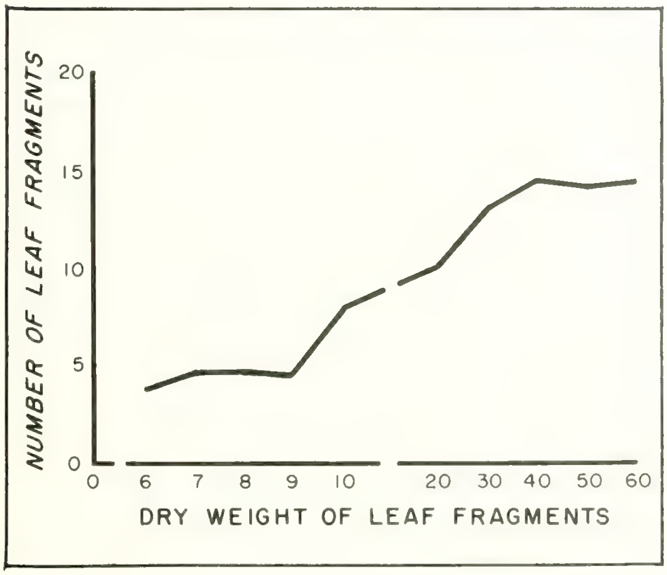

Figure 13.—*Relationship between number of leaf fragments per microscope field (125 ×) to dry weight (g × 10^{-3}) of leaf fragments used to prepare slides having 22 × 40 mm cover slips.*

Five different test mixtures were made by mixing different proportions of ground mushroom (5 – 30%) with different proportions of leaves from *Schizachyrium tenerum, Eragrostis spectabilis, Desmodium ciliare* and *Lonicera japonica.* Five microscope slides were made for each test mixture. Quantification was performed in two steps. First, the slides were examined separately at 125 × for plant leaf fragments and at 500 × for spores; 20 fields were examined in each case. All plant fragments or spores occurring in each field were counted and an average particle density

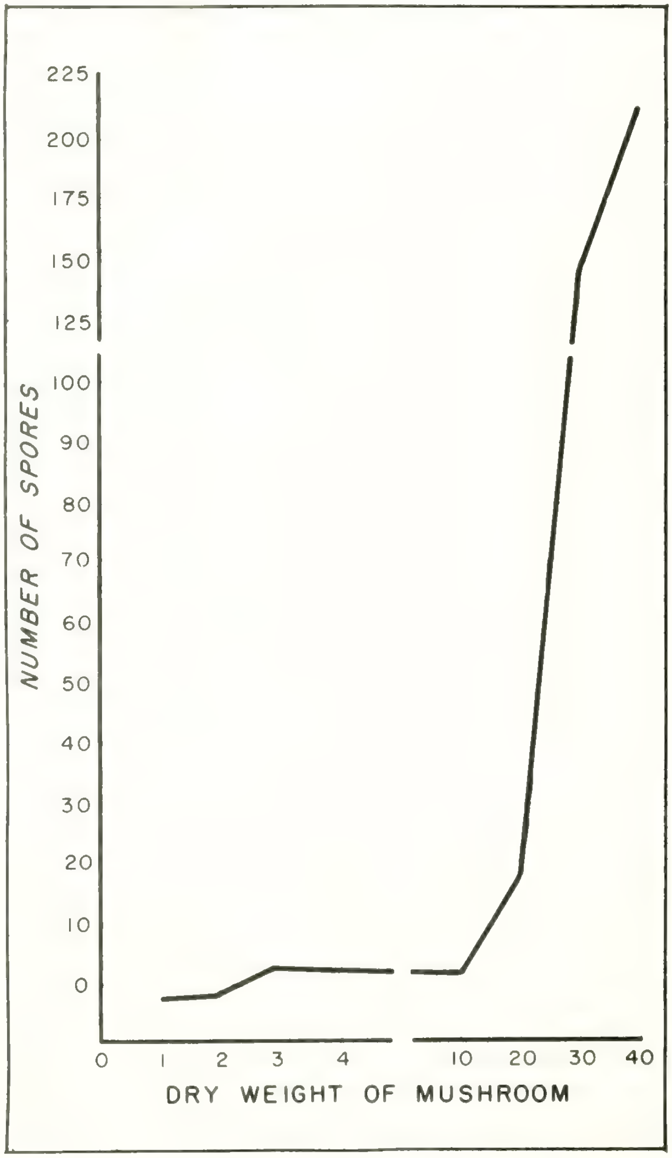

Figure 14.—*Relationship between number of* Amanita *sp. spores per microscope field (500 ×) to dry weight (g × 10^{-3}) of dry mushroom used to prepare slides having 22 × 40 mm cover slips.*

Table 1.—*Comparison of known proportions (%) of plant leaves and mushroom in five test mixtures with estimates obtained from particle densities of leaf fragments and spores*

Species in test mixture	Test	Estimate	Test	Estimate	Test	Estimate	Test	Estimate	Test	Estimate
Schizachyrium tenerum	50	35	40	35	30	18	40	25	20	10
Eragrostis spectabilis	10	10	20	11	15	5	10	6	10	5
Desmodium ciliare	25	34	20	37	15	14	10	24	10	3
Lonicera japonica	10	10	10	4	20	49	10	17	10	4
Amanita sp.	5	11	10	13	20	14	30	28	50	78

was calculated by dividing the total number of plant leaf fragments or spores by the number of fields examined. The dry weight represented by each particle density was estimated by using figure 13 for plant leaves and figure 14 for mushrooms. Relative dry weights of mushroom and plant leaves in the mixtures were estimated by calculating the relative contribution of each from estimates of their dry weights on slides.

The second step in quantification was performed by calculating relative particle densities of leaves according to the procedures described earlier (Sparks and Malechek 1968), and multiplying by the proportion of leaf fragments in each mixture.

Using this procedure known and estimated proportions for mushrooms in the simulated diet were similar except when the proportions of mushrooms were 50% (table 1). At this level the number of spores per field became too numerous for accurate estimates. Based on earlier analyses the number of spores per field from diet sample slides should remain below 20. The accuracy of estimating plant leaf compositions using the same slides is not affected.

Data for leaf particle densities should apply to other situations while data for mushrooms applies only to the species we used. This procedure should be repeated for each mushroom species and each phenological stage.

Mast

Most wildlife husk nuts before eating them, and even though deer often swallow acorns whole, the shells may be regurgitated and spit out. In fragmented form, acorn hulls are difficult to identify and mast (endosperm) is amorphous. Since mast is highly digestible, it is rarely found in fecal material. We have observed mast in fecal pellets of deer and goats that feasted on abundant supplies. In these cases the bulk of material ingested was probably too much for complete digestion.

Regardless of these problems, there are ways to identify the tree that produced the mast found in stomach, rumen or fecal samples. First, all acorns have some trichomes on the hulls. These are brittle, become detached and remain in the digestive tract passing through to the feces. Microhistological examination and comparison with reference material allows identification of species when trichomes are not similar. Quantification can be performed by learning to estimate percentages of mast in mixtures from frequency counts of trichomes on slides (table 2).

Differences in shapes of starch cells in the mast from different acorns have been detected (Korschgen 1981). Reference slides can be made from scrapings of the endosperm and mast in stomachs can be identified from water mounts of the semi-digested starch. This method has not been widely investigated but may be useful for food habits work with a variety of granivores.

QUALITY CONTROL

A technician's behavior and performance can change from day to day because identification is basically a value judgment. This human source of error cannot be overcome through the employ of correction equations or equivalence factors regardless of how they are calculated.

Most plants can be identified through some of the fragments. However, we found it necessary to ignore the presence of any trichomes that were not attached to fragments to avoid over estimation of such species' contribution to diet samples.

Different strategies may be needed for each situation. For example, every fragment of a grass could be identified if it was mixed with dicots. Test mixtures of 2 to 6 different plants are adequate to periodically check a technicians accuracy. Test slides are also valuable for building technician confidence during training periods. There are so many ways to combine plants in mixtures that it is impractical to produce enough tests to simulate every possible combination of foods in actual diet samples. Tests sometimes have to be made after the plants in a mixture are identified, but before they are quantified. Sources of error and uniqueness of mixtures make microhistological techniques both an art and a science (Johnson and Pearson 1981), but a regimented sampling procedure is necessary to provide consistent results.

Table 2.—*Comparison of known and estimated proportions (%) of mast in five mixtures with plant leaf fragments. Mast was quantified by counting acorn trichomes*

Species in test mixture	Test	Estimate	Test	Estimate	Test	Estimate	Test	Estimate	Test	Estimate
Quercus rubra (acorns)	50	54	25	19	25	21	40	40	10	20
Quercus rubra (leaves)	....	....	....	....	25	22	....	....	....	....
Rubus sp.	....	....	....	....	25	29	....	....	40	39
Lonicera japonica	....	....	....	....	....	....	25	27	10	17
Gelsemium sempervirens	....	....	....	....	25	28	15	16	40	24
Smilax rotundifolia	....	....	25	34	....	....	20	17	....	....
Toxicodendron radicans	50	46	50	47	....	....	....	....	....	....

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Appendix I – Directions for Preparation of Mounting Media

Directions for Preparing Hoyer's Solution

Chloral hydrate crystals	200 g
Glycerine	20 ml
Gum arabic (photopurified)	30 g
Tap water	50 ml

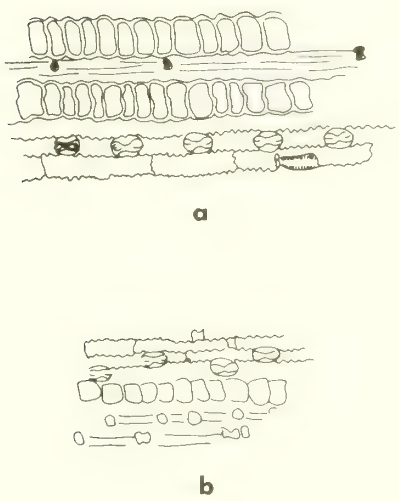
Combine chloral hydrate and glycerine. Add gum arabic and water. Place container in a hot water bath and stir until ingredients are combined.

Directions for Preparing Plastic Mounting Medium

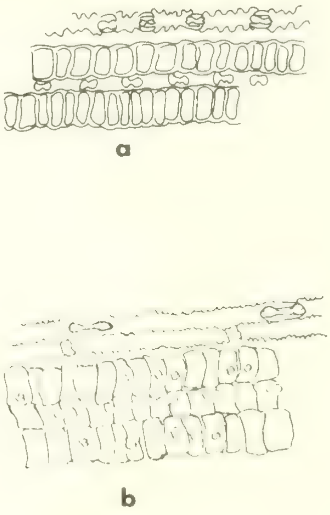
Phenol crystals	400 g
Lactic acid	440 ml
Polyvinyl alcohol beads	150 g
Distilled water	1120 ml

Add phenol crystals to lactic acid and stir until dissolved. Work should be performed in a ventilated hood. Mix polyvinyl alcohol beads with water in a hot water bath. Combine the two solutions and stir while keeping the mixture warm in a hot water bath.

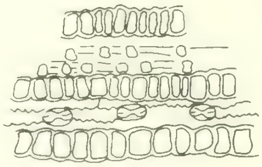
Appendix II – Drawings of Plant Fragments Under Phase-Contrast Microscopy



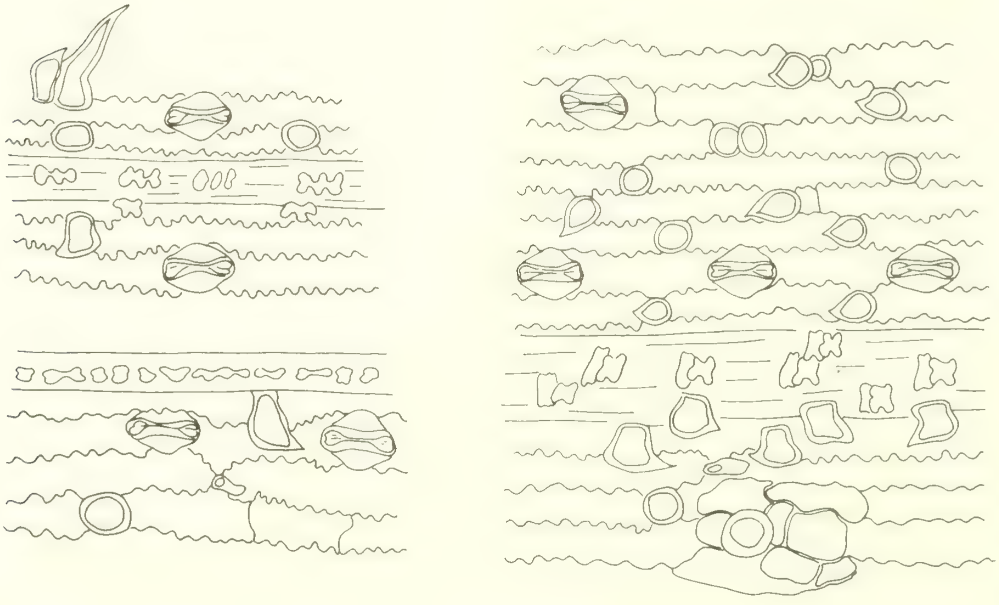
Purple lovegrass (*Eragrostis spectabilis*) (a) and tridens (*Tridens* spp.) (b)—Stomata are small and have rounded domes. Fragments may have prickles but are without other types of trichomes.



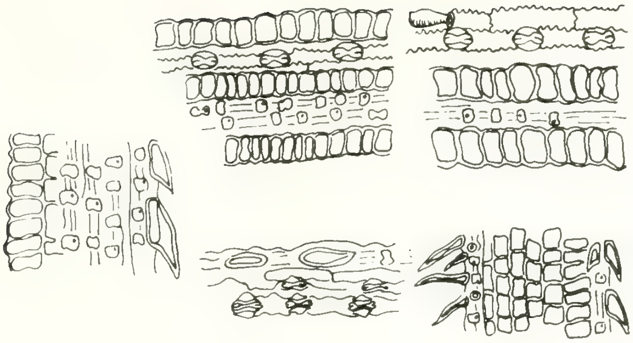
Bearded skeletongrass (*Gymnopogon ambiguus*) (a) and switchgrass (*Panicum virgatum*) (b)—Silica bodies are dumbbell-shaped but compared to bearded skeletongrass, switchgrass stomata are larger and adjoining cell walls are tightly sinuous or scalloped.



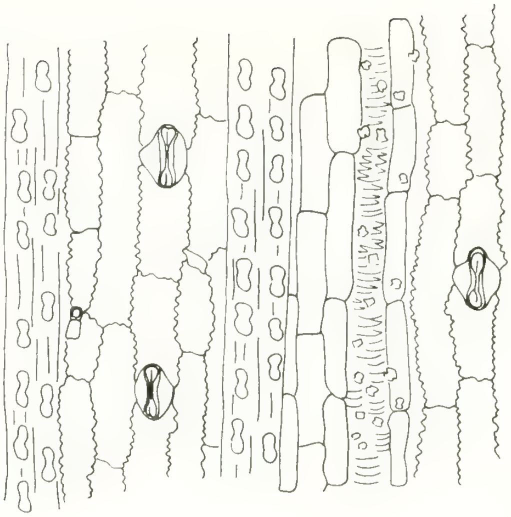
Sedges (*Carex* spp.)—Shiny, pappillae are common. Cells are square or rectangular with wavy walls.



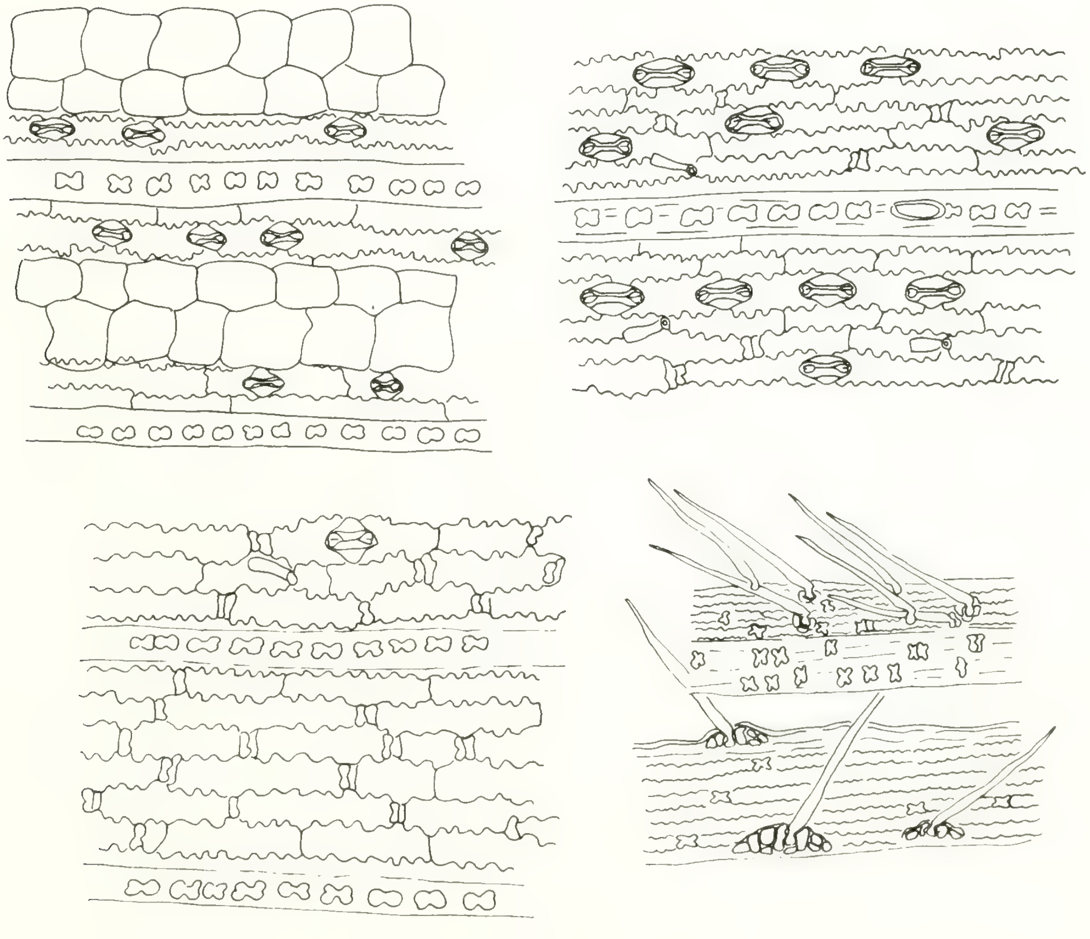
Paspalums (*Paspalum* spp.)—Silica bodies resemble butterflies. Some have cuboid companion cells.



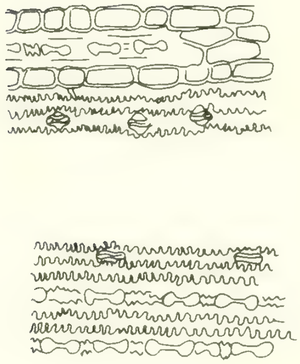
Cutover muhly (*Muhlenbergia expansa*)—Stomata are small with peaked domes. Fragments may have many short trichomes. Costal girders are square.



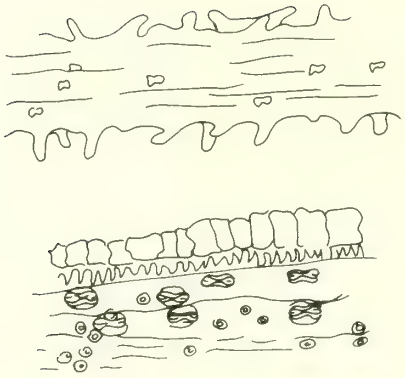
Green silkyscale (*Anthaenantia villosa*)—Stomates are mostly rounded but some are slightly peaked. Most silica bodies look like peanuts.



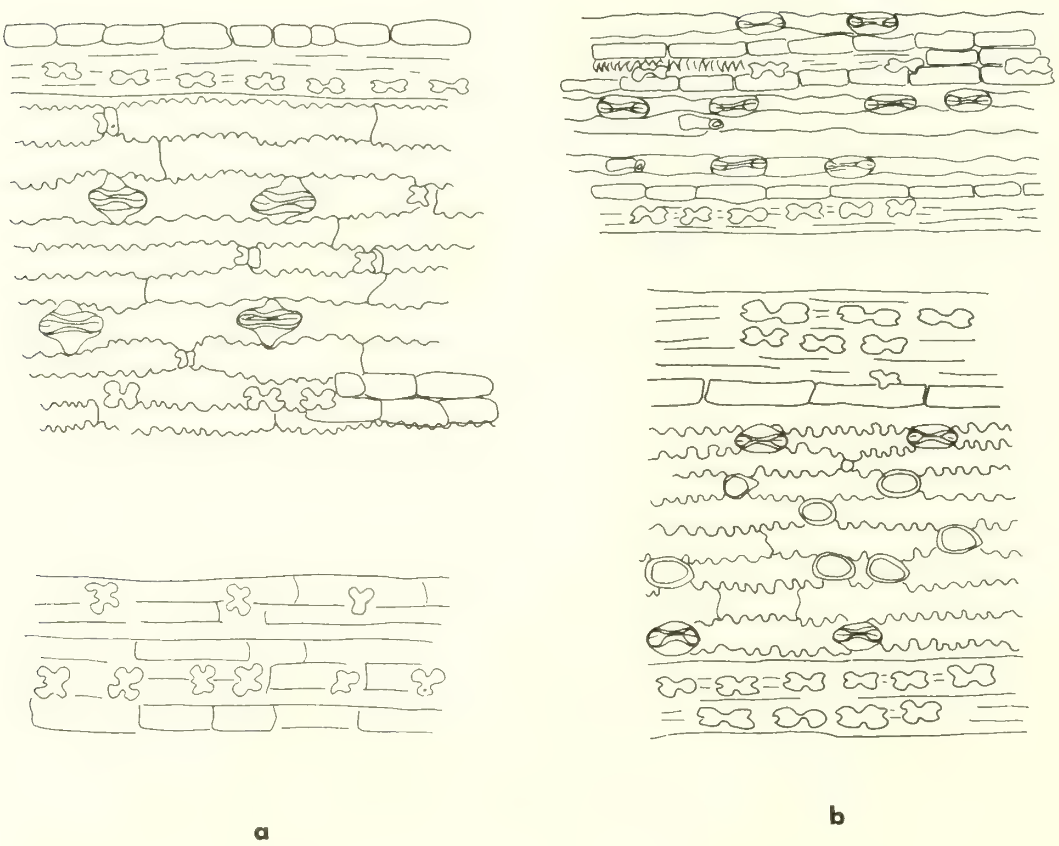
Panic grasses (*Panicum* spp.)—Relatively long bone-shaped silica bodies resemble 8's.



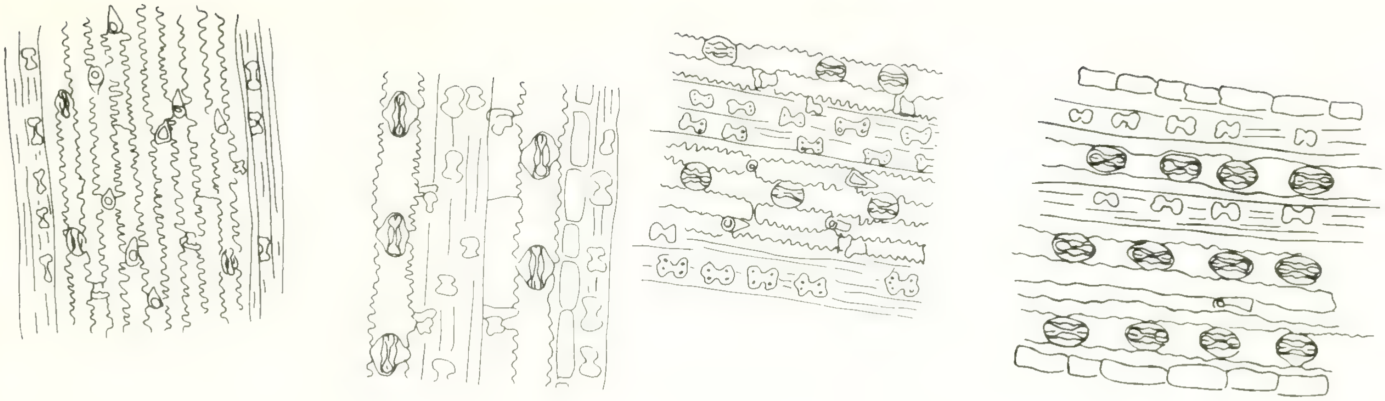
Threeawns (*Aristida* spp.)—Silica bodies are dumbbell-shaped with rounded ends. Stomata have peaked domes and look nearly triangular. Cell walls in the intercostal area are deeply sinuous.



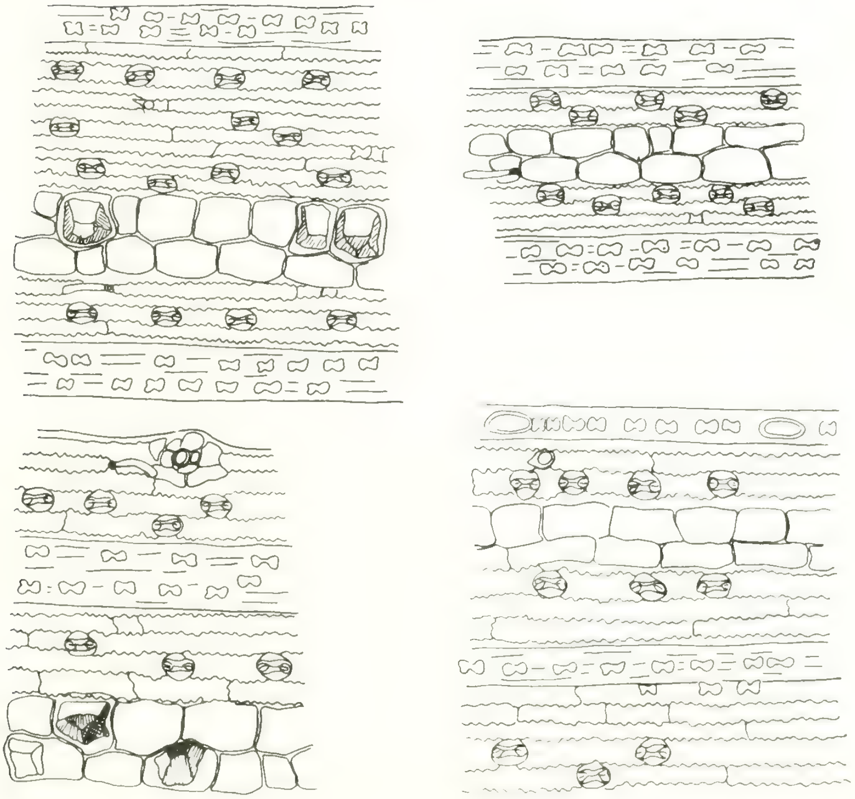
Pineywoods dropseed (*Sporobolus junceus*)—Papillate protrusions of epidermal cells are similar to those of sedges. Vein silica bodies and companion cells form couples. Stomates are small and round.



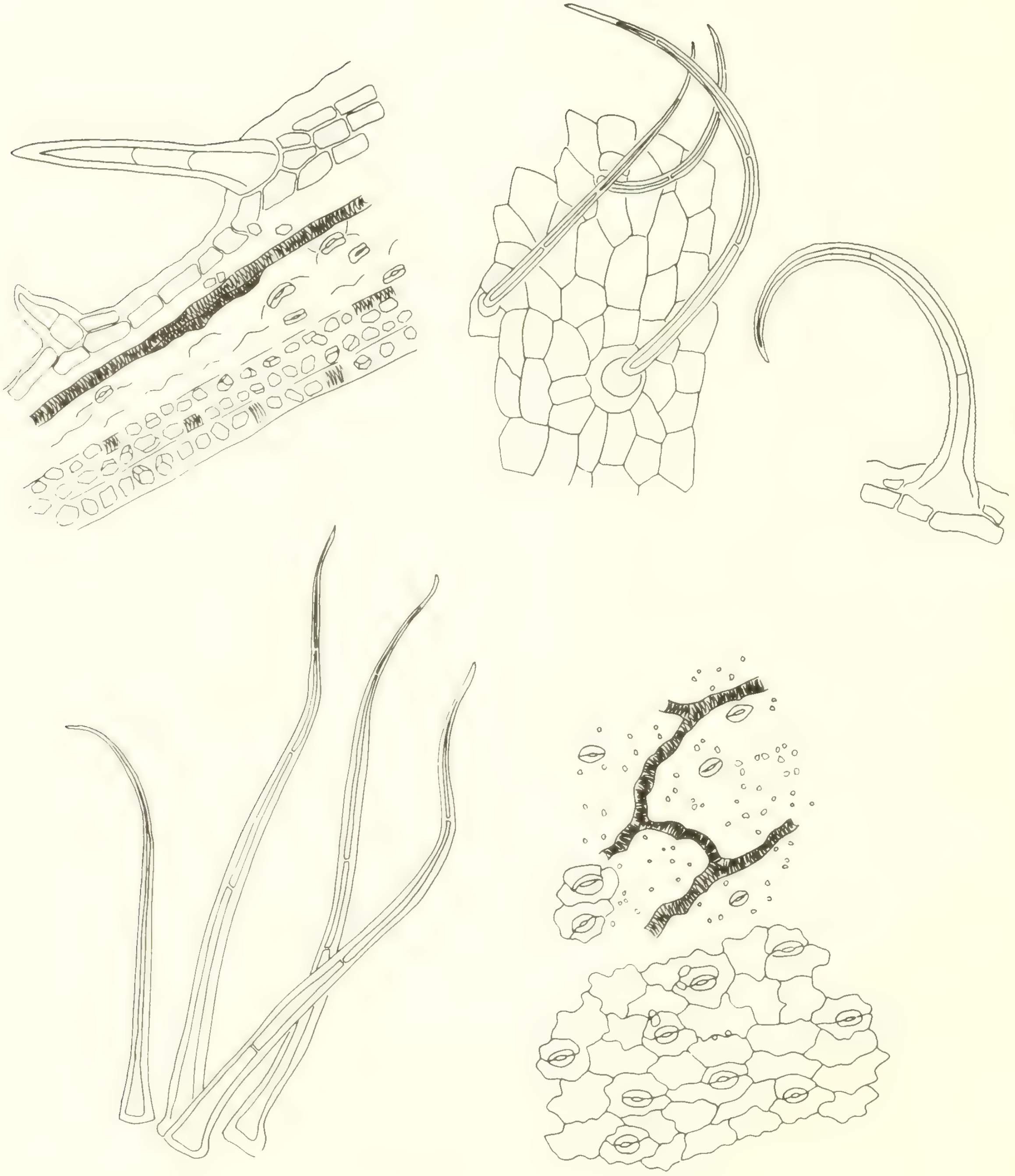
Common carpetgrass (*Axonopus affinis*) (a) and yellow indiangrass (b) (*Sorghastrum nutans*) —Dumbbell-shaped silica bodies are deeply notched. Carpetgrass stomates are triangular while those of indiangrass are oval-shaped.



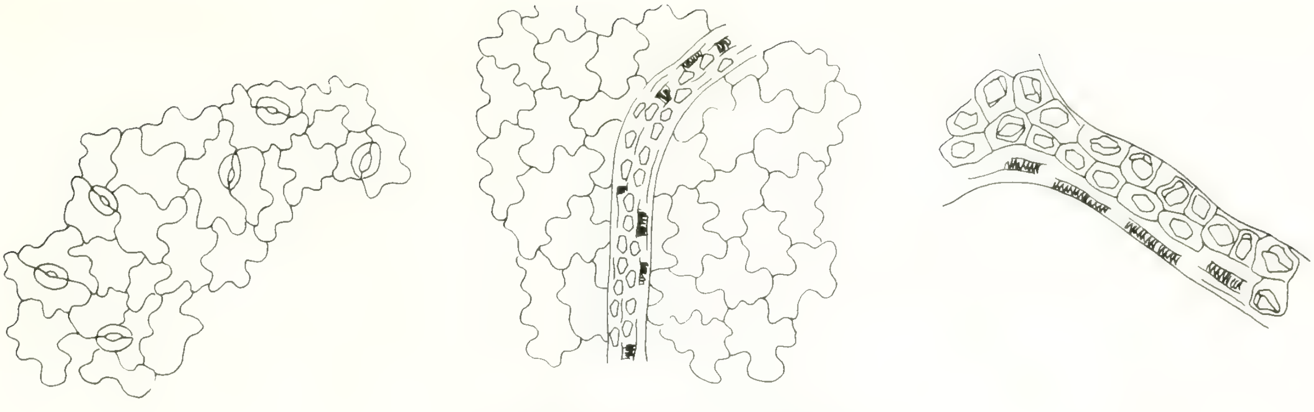
Bluestems (*Andropogon* spp., *Schizachyrium* spp.)—Stomata are triangular. Silica bodies are dumbbell-shaped with notched ends.



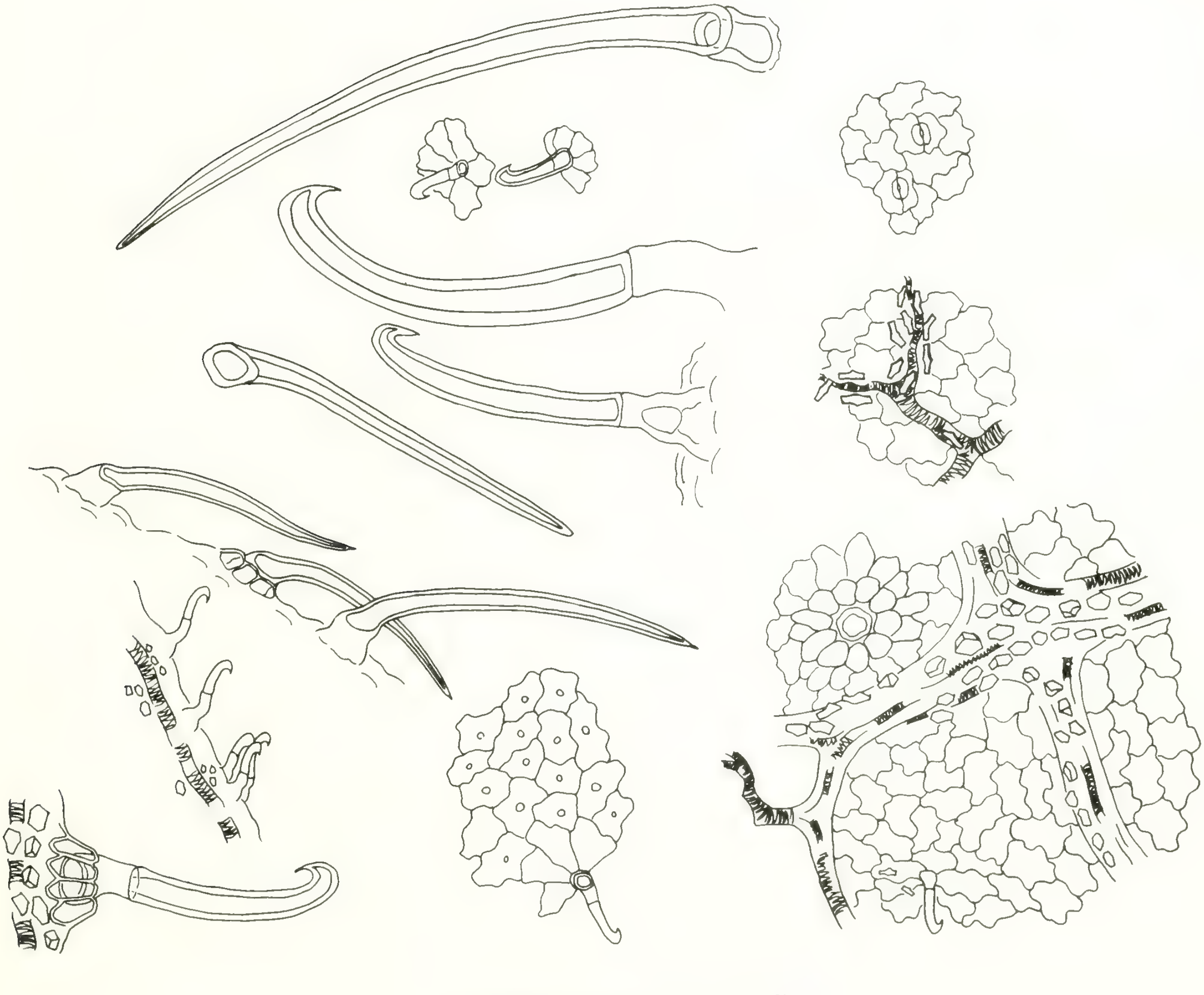
Spike uniola (*Chasmanthium laxum*)—Bulliform cells may contain crystals. Silica bodies are short, small dumbbells that may look like bow ties.



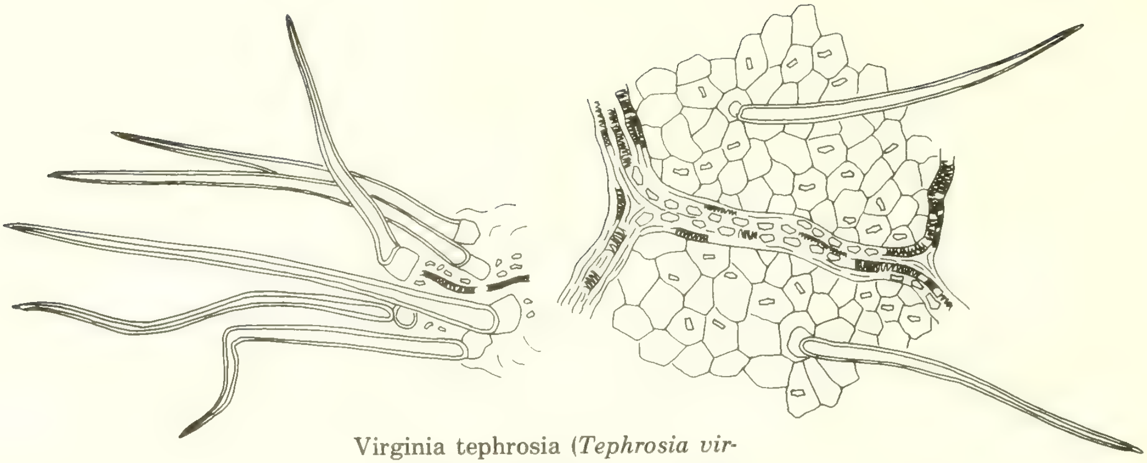
Partridgepea (*Cassia fasciculata*) —Unicellular strap-shaped trichomes are internally segmented. Square crystals are most abundant over veins.



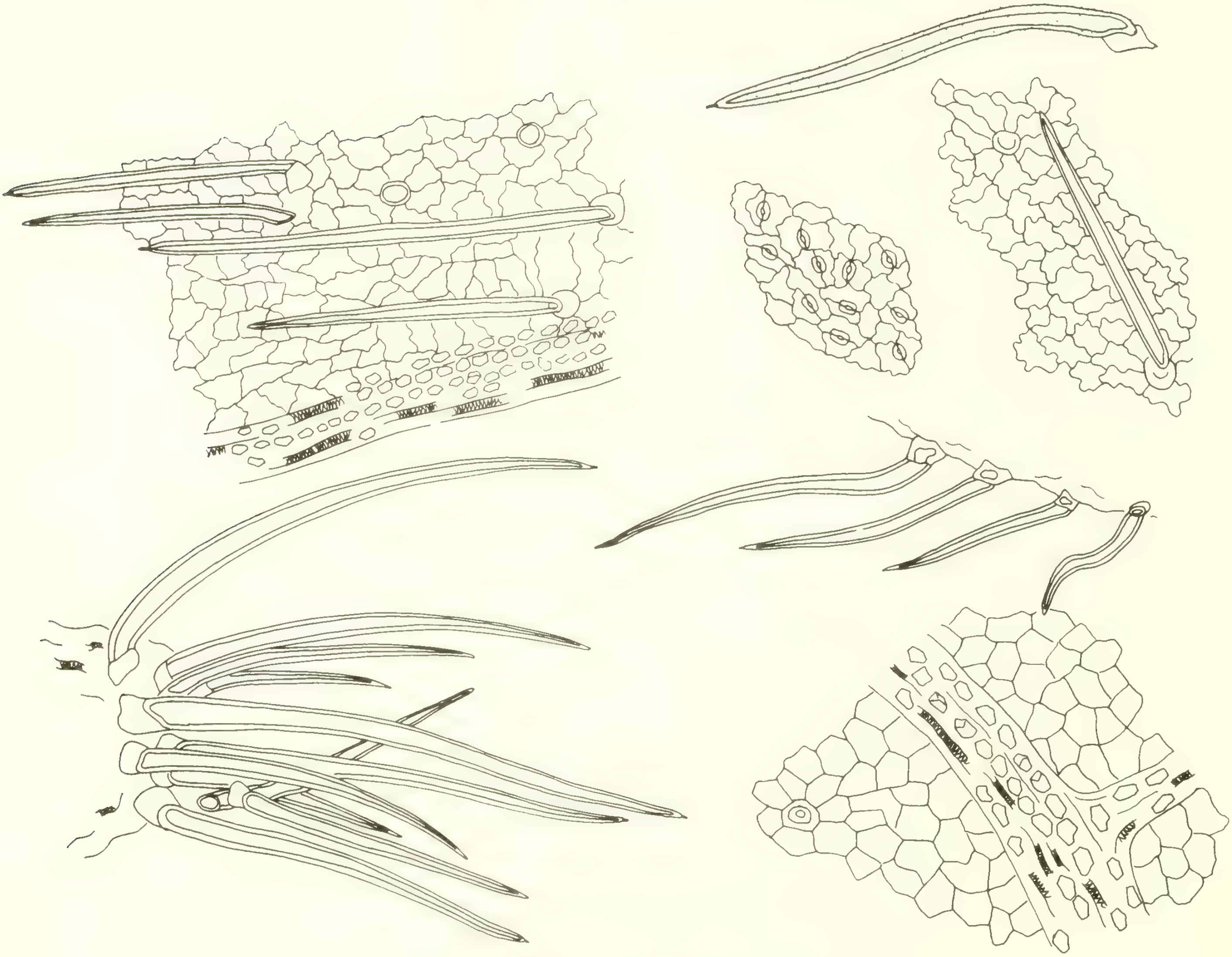
Pigeonwings (*Clitoria mariana*)—Fragments are without trichomes and numerous square crystals cover the veins.



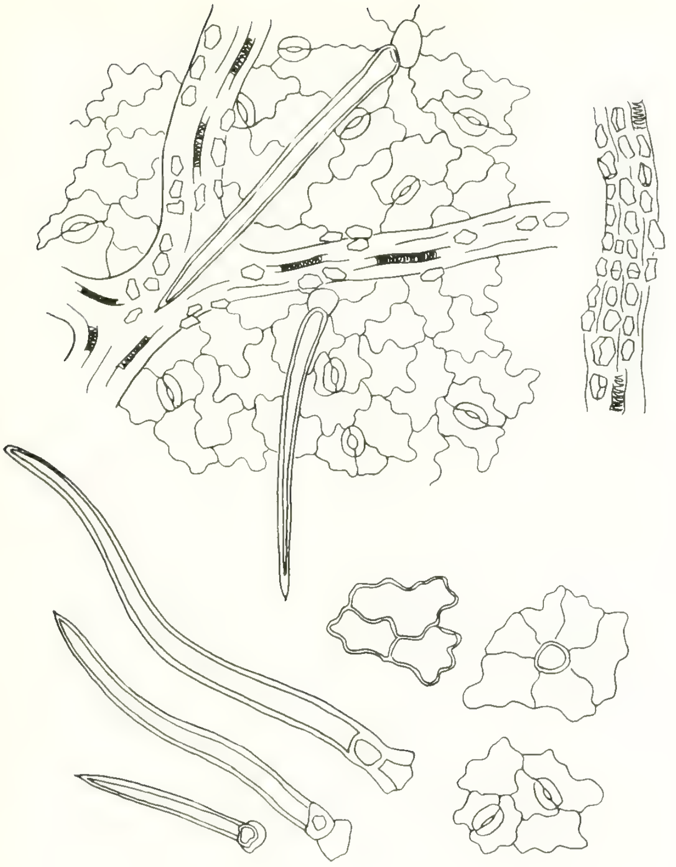
Littleleaf tickclover (*Desmodium ciliare*)—Three types of trichomes can be observed; one has a mucronate tip, two have hooked tips. All trichome bases are separate, single cells. Square crystals cover the veins.



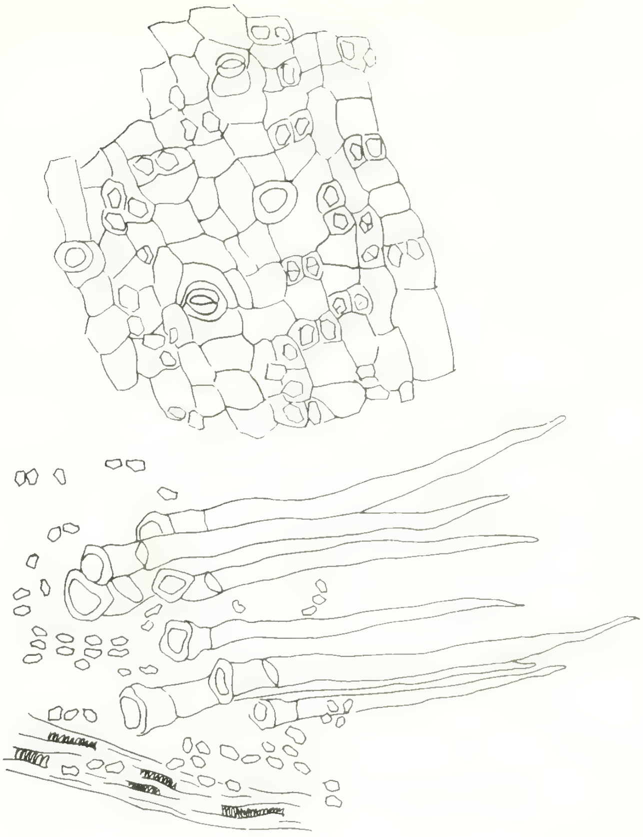
Virginia tephrosia (*Tephrosia virginiana*)—Trichomes are stiff and tapered with mucronate tips, and have a 1-celled, round base. Square and rectangular crystals are abundant.



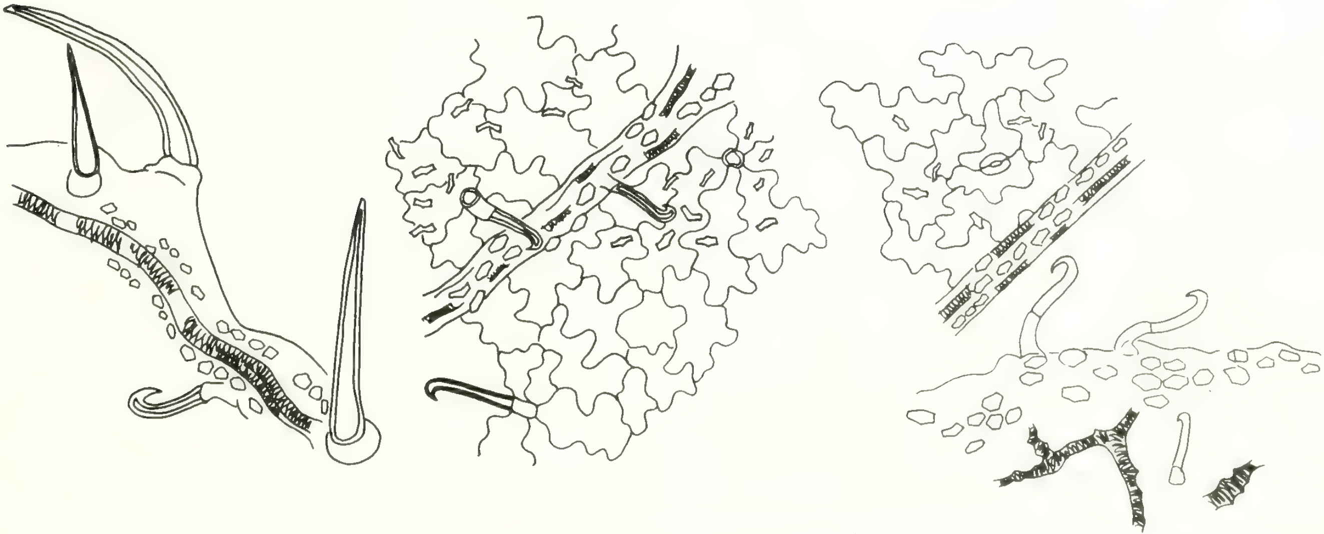
Lespedezas (*Lespedeza* spp.)—Trichomes are flexible with mucronate tips. Surfaces of trichomes are often ciliate in *L. virginica*; sometimes ciliate in *L. hirta*.



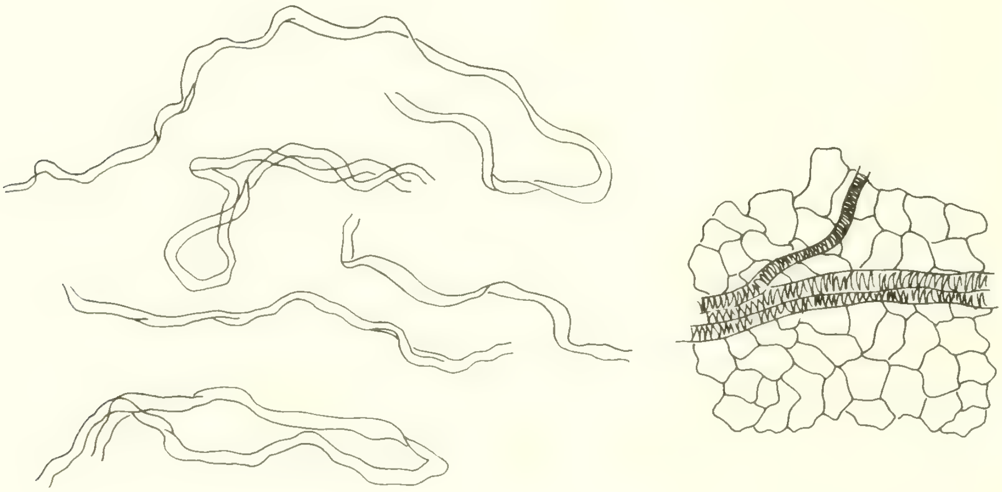
Downy milkpea (*Galactia volubilis*)—Trichomes are stiff with a mucronate tip and 1-celled base. Intercostal cells are puzzle-like. Square crystals are mostly over the veins.



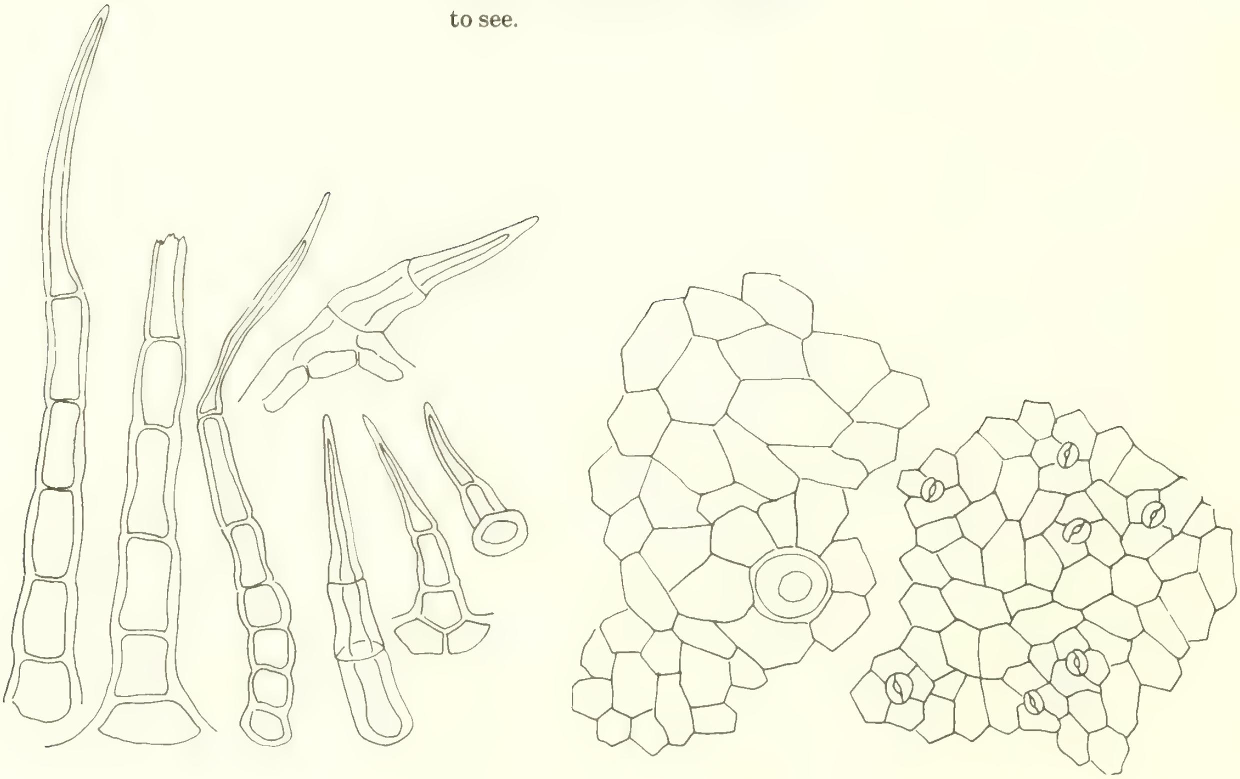
Pencilflower (*Stylosanthes biflora*)—Trichomes appear wilted and have a 1-celled base. Square crystals are very abundant.



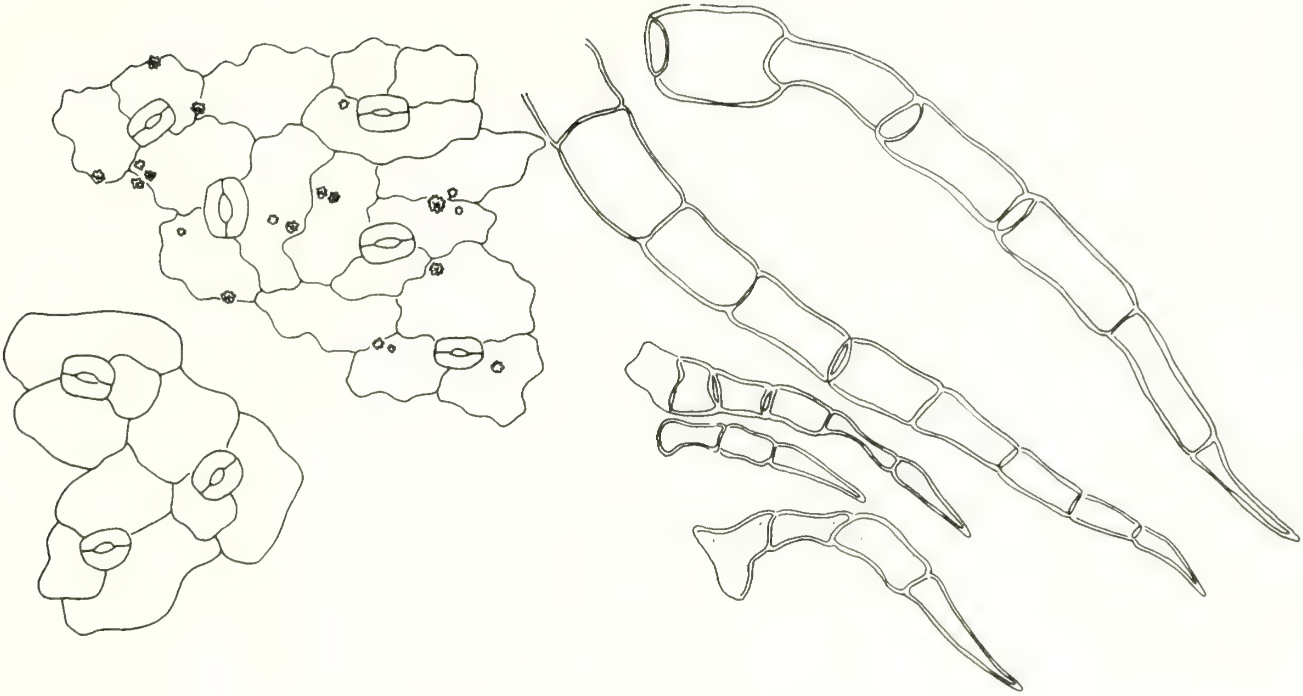
Butterfly pea (*Centrosema virginianum*)—This plant resembles *Desmodium* and *Galactia*. Two types of trichomes are present; one is large with mucronate tips, the other is smaller with hooked tips. Square and rectangular crystals are present.



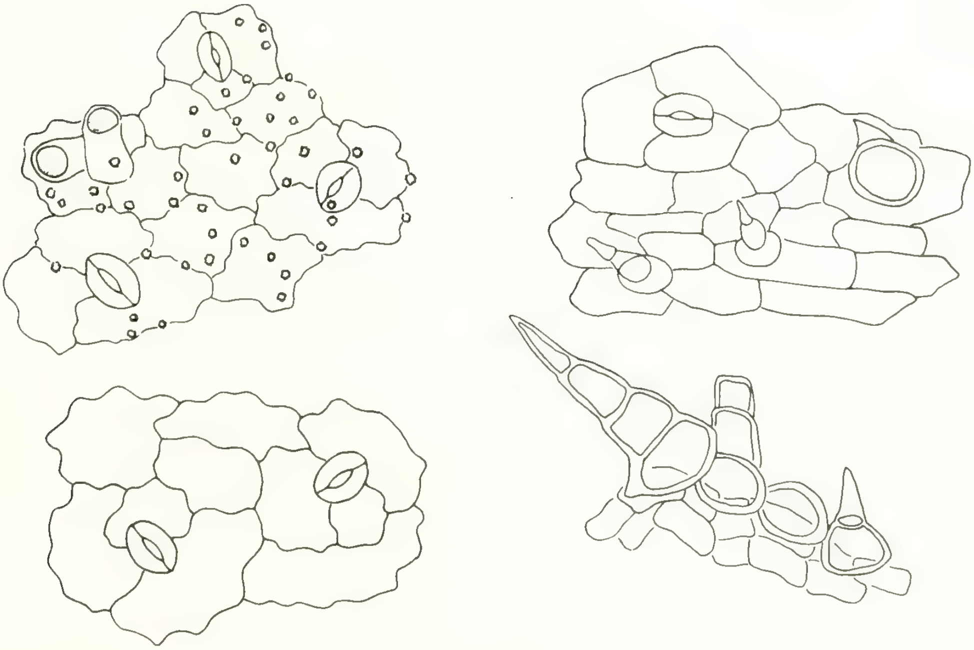
Hymenopapus (*Hymenopappus artemisiifolius*)—Flattened, ribbon-like trichomes look like spaghetti. No crystals appear in tissue. Cells walls are very thin so that tissues are difficult to see.



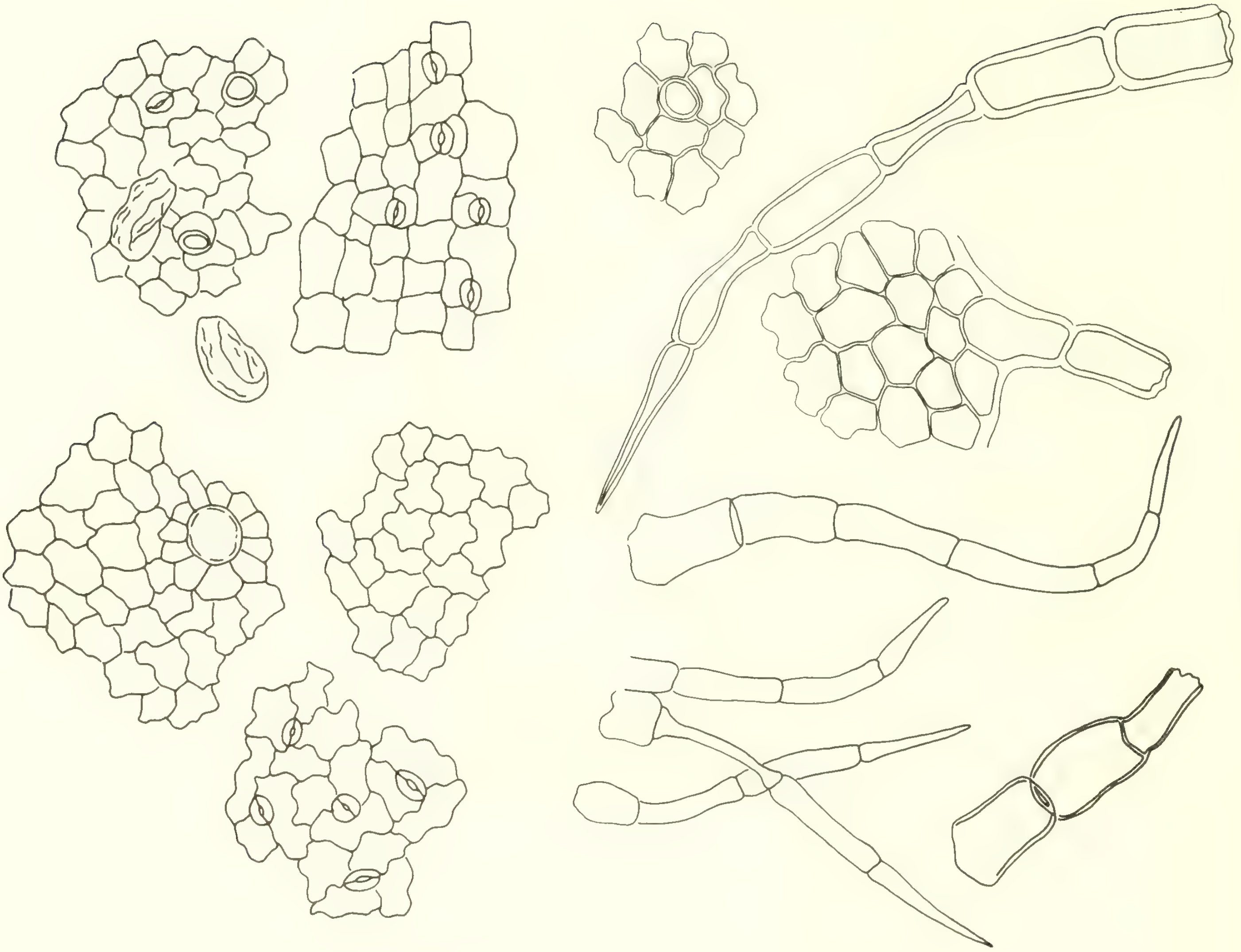
Goldenrod (*Solidago rugosa*)—Ligulate, segmented trichomes have thick walls. Flared bases are usually broken off. Intercostal cells are angular.



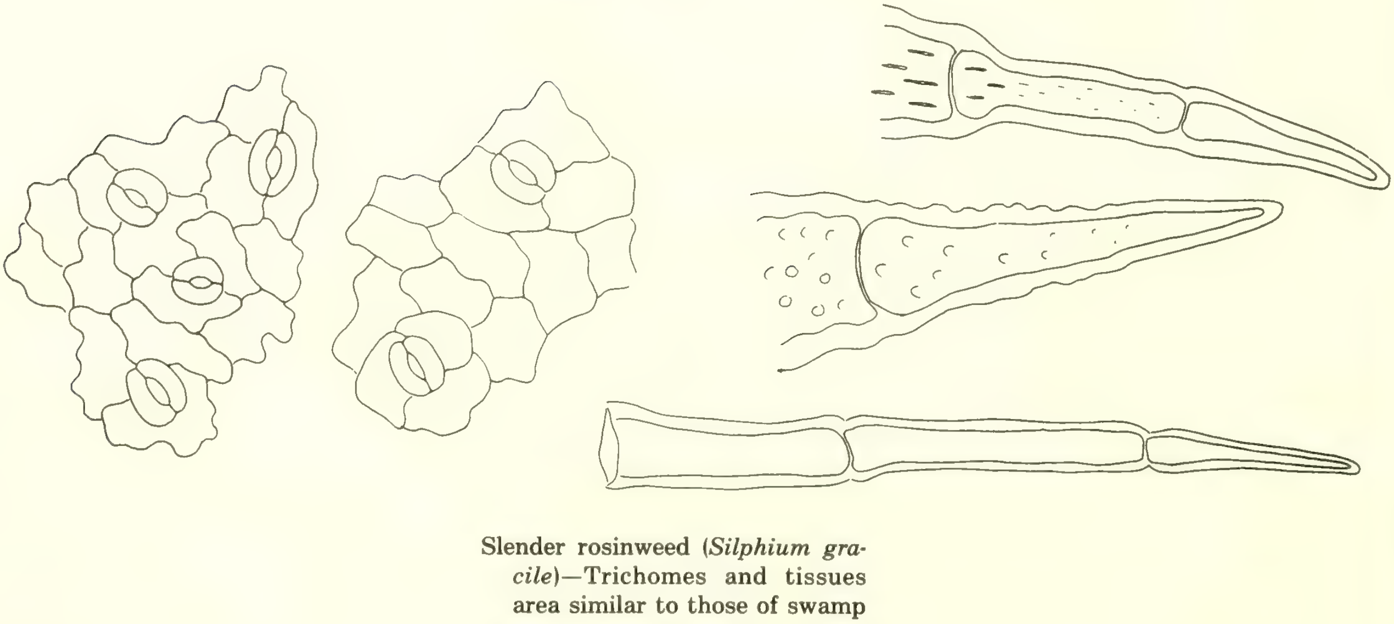
Thickleaf coreopsis (*Coreopsis lanceolata*)—Segmented trichomes are ligulate. Small druses have slightly lobed cells.



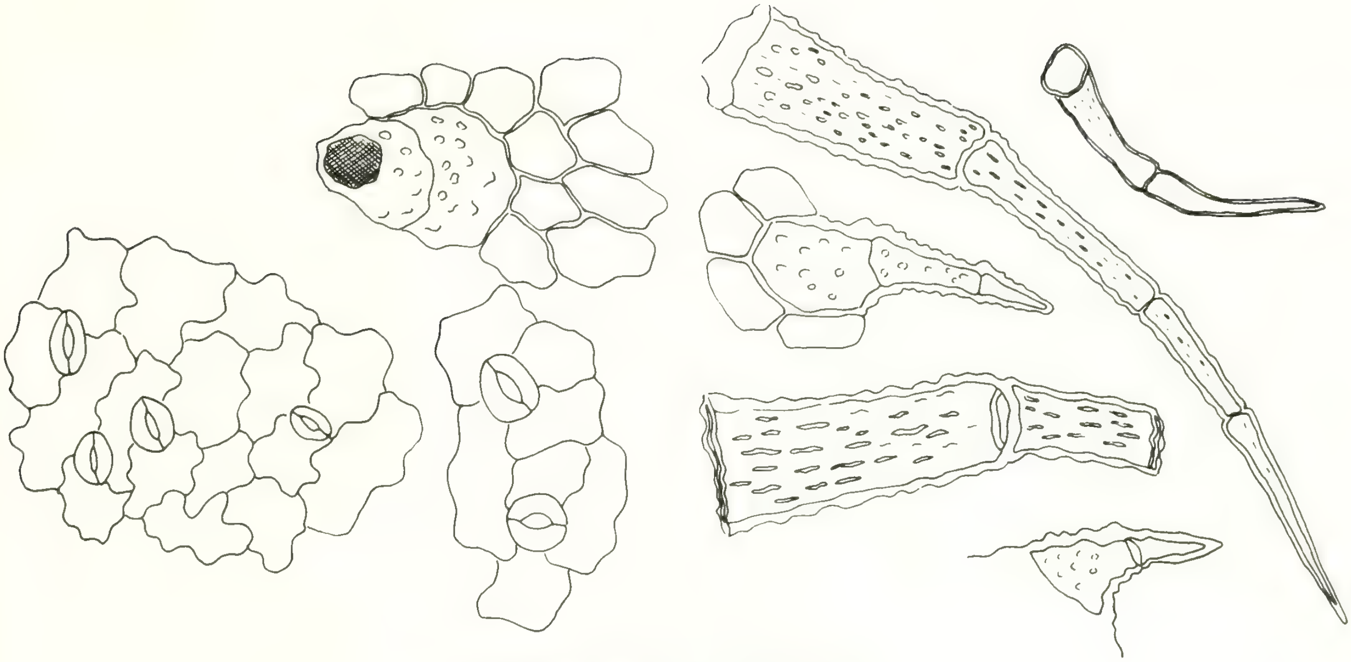
Grassleaf goldaster (*Heterotheca graminifolia*)—Segmented trichomes are ligulate. Very small druses occur intercostally with slightly lobed cells.



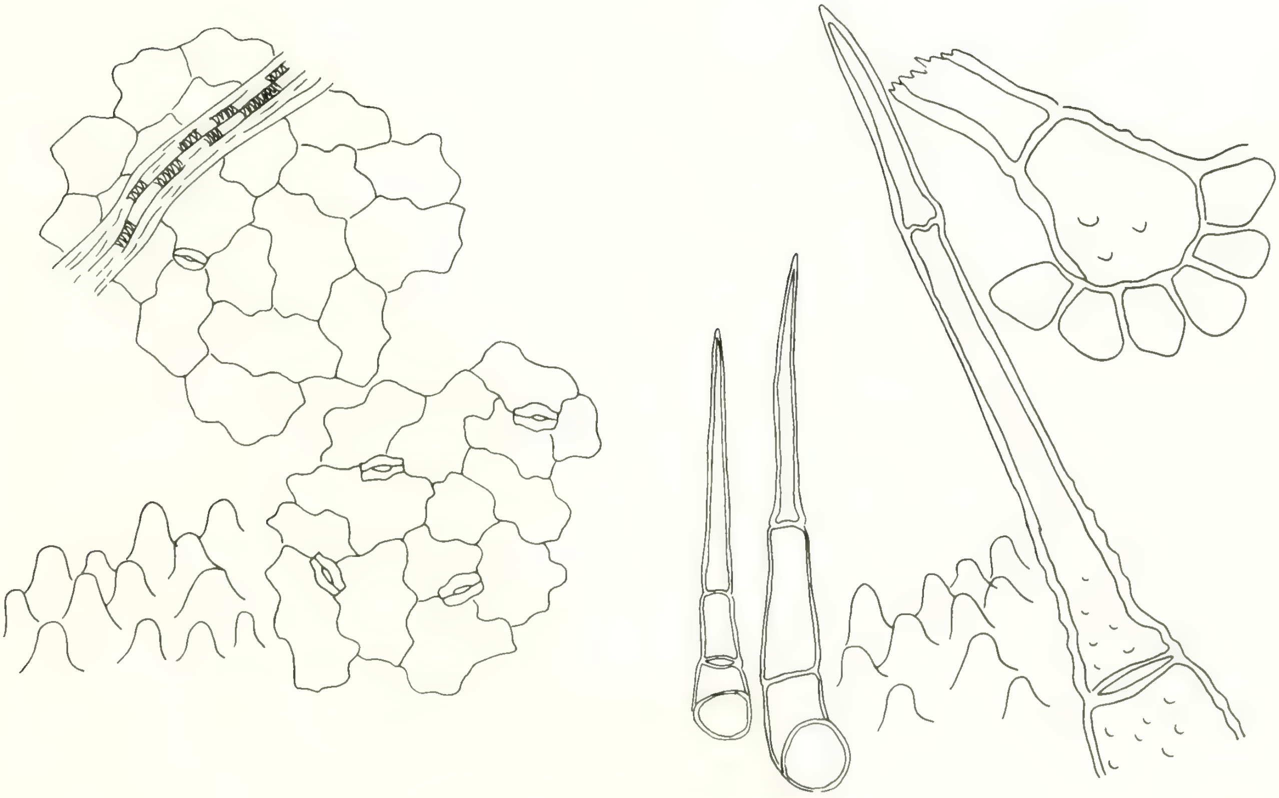
Eupatoriums (*Eupatorium* spp.)—Ligulate, segmented trichomes and silica flowers are present. Intercostal cells are angular with wavy walls.



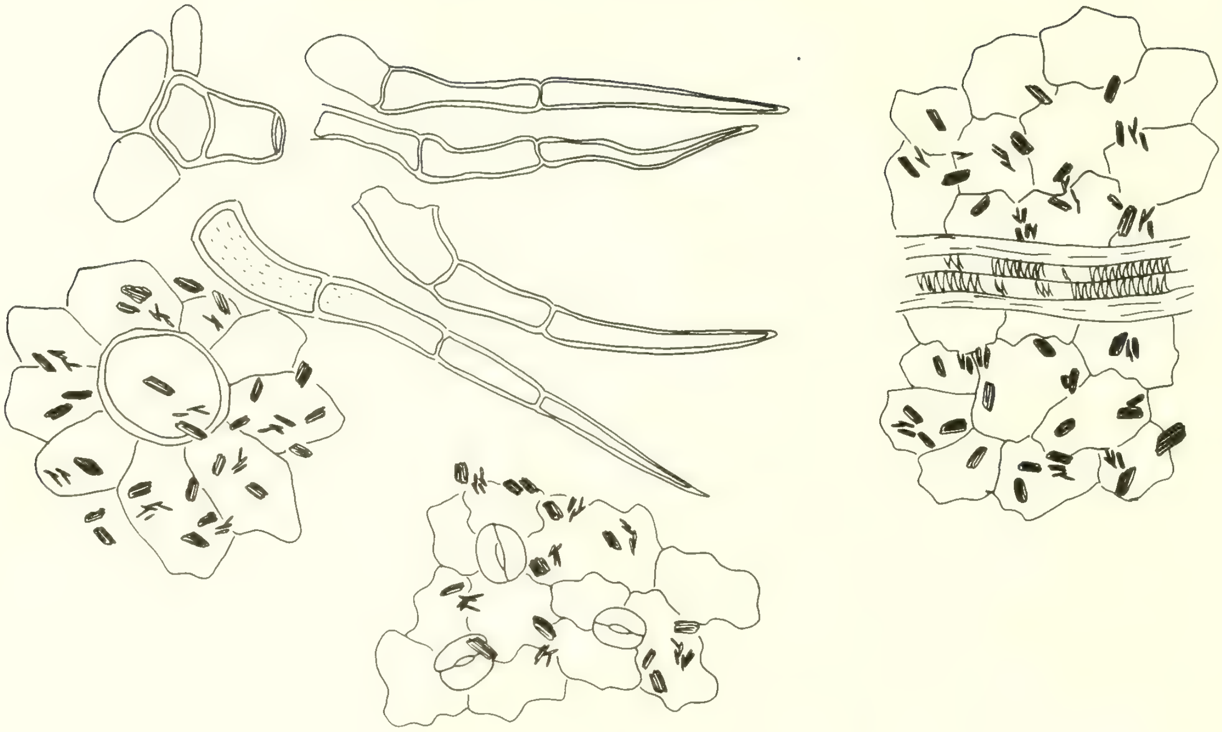
Slender rosinweed (*Silphium gracile*)—Trichomes and tissues area similar to those of swamp sunflower.



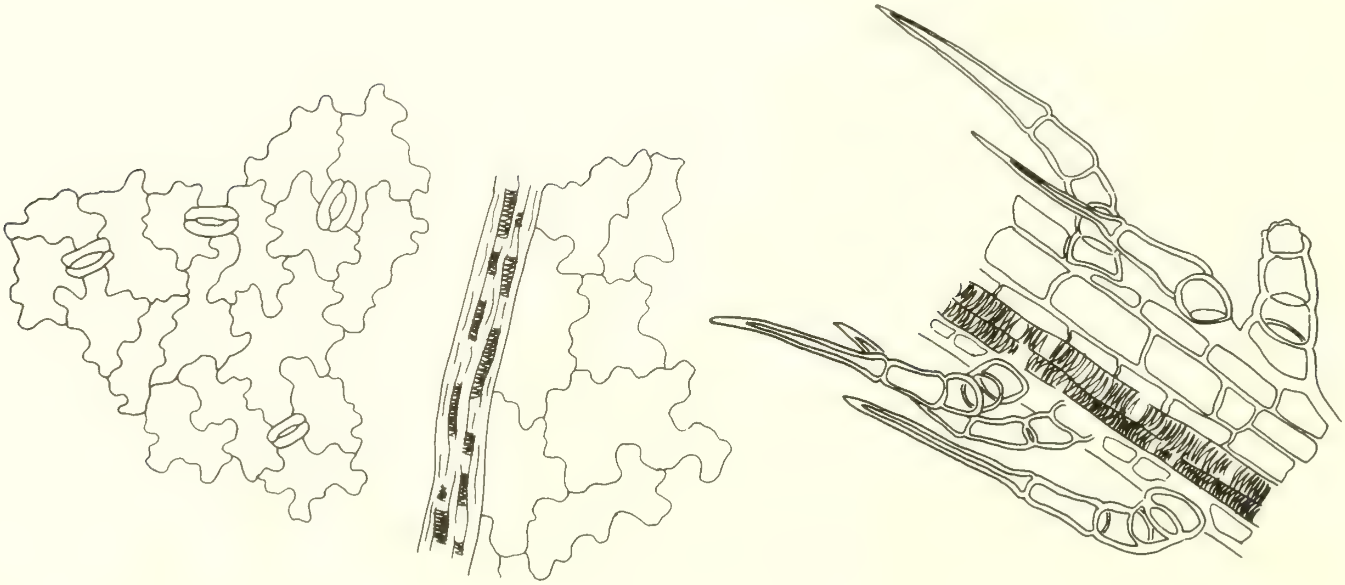
Swampsunflower (*Helianthus angustifolius*)—Large, segmented trichomes have thick bumpy surfaces. Distinct attachment cells in tissue are made up of large thin-walled cells and druses are present.



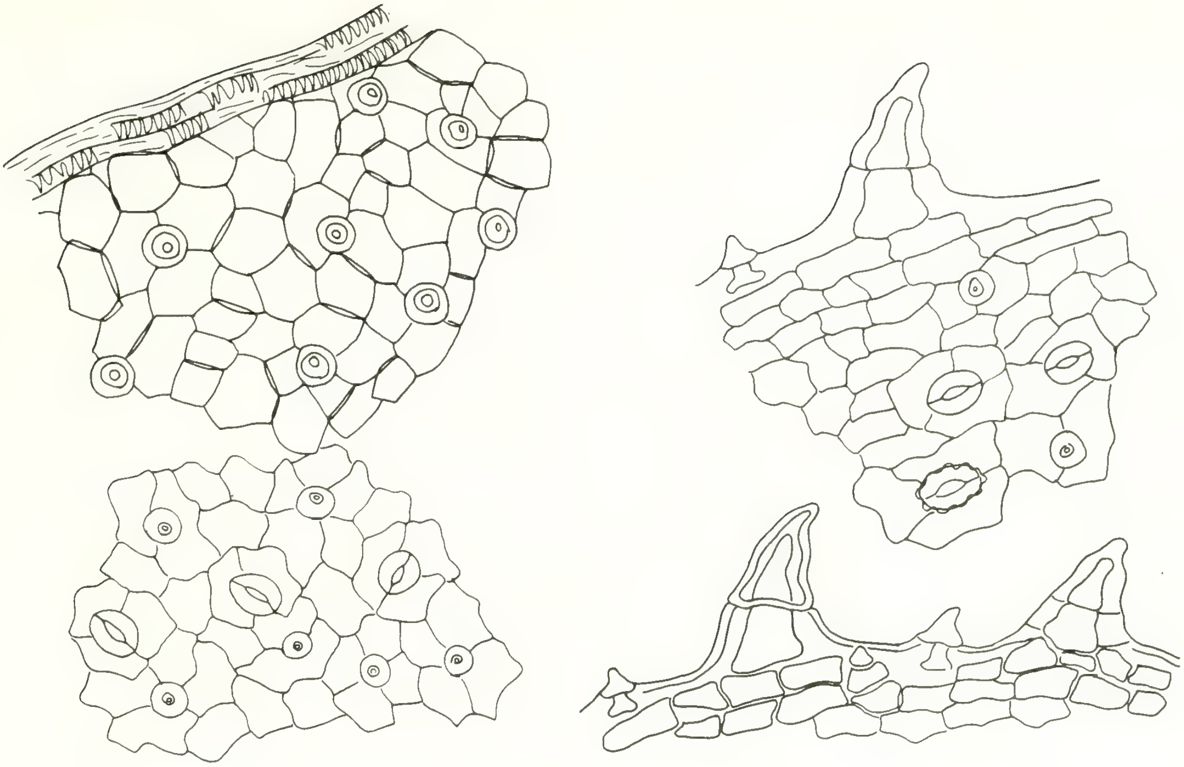
Blackeyed susan (*Rudbeckia hirta*) —Large, ligulate, segmented trichomes are present.



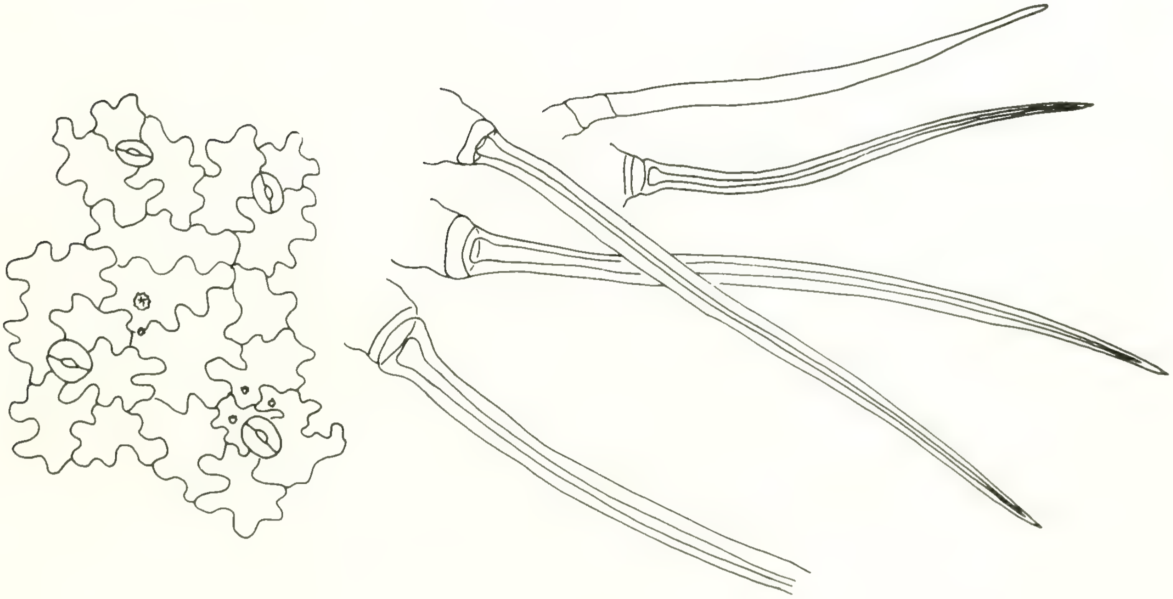
Plantainleaf coneflower (*Rudbeckia grandiflora*)—Medium, ligulate, segmented trichomes are present. Small raphides are very abundant.



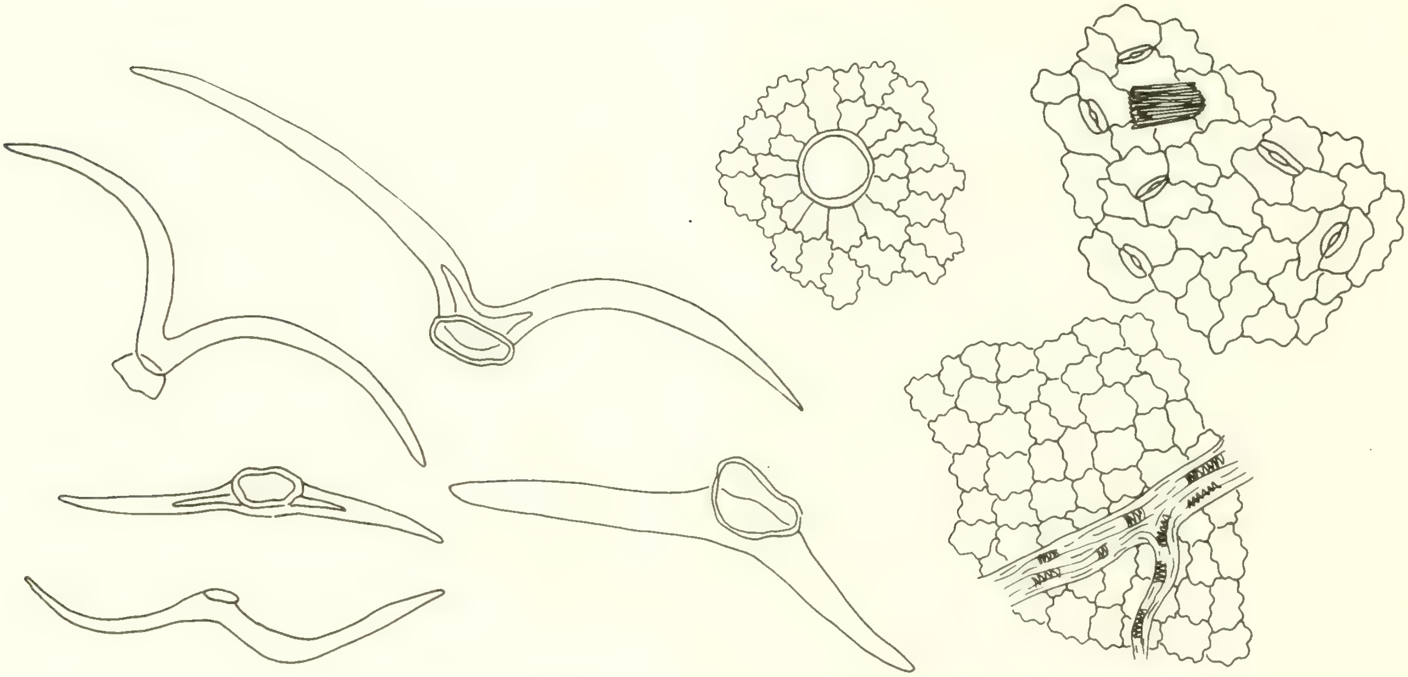
Daisy fleabane (*Erigeron strigosus*)—Segmented trichomes appear jointed. Leaf cells are usually puzzle-like while stem cells are rectangular and parallel.



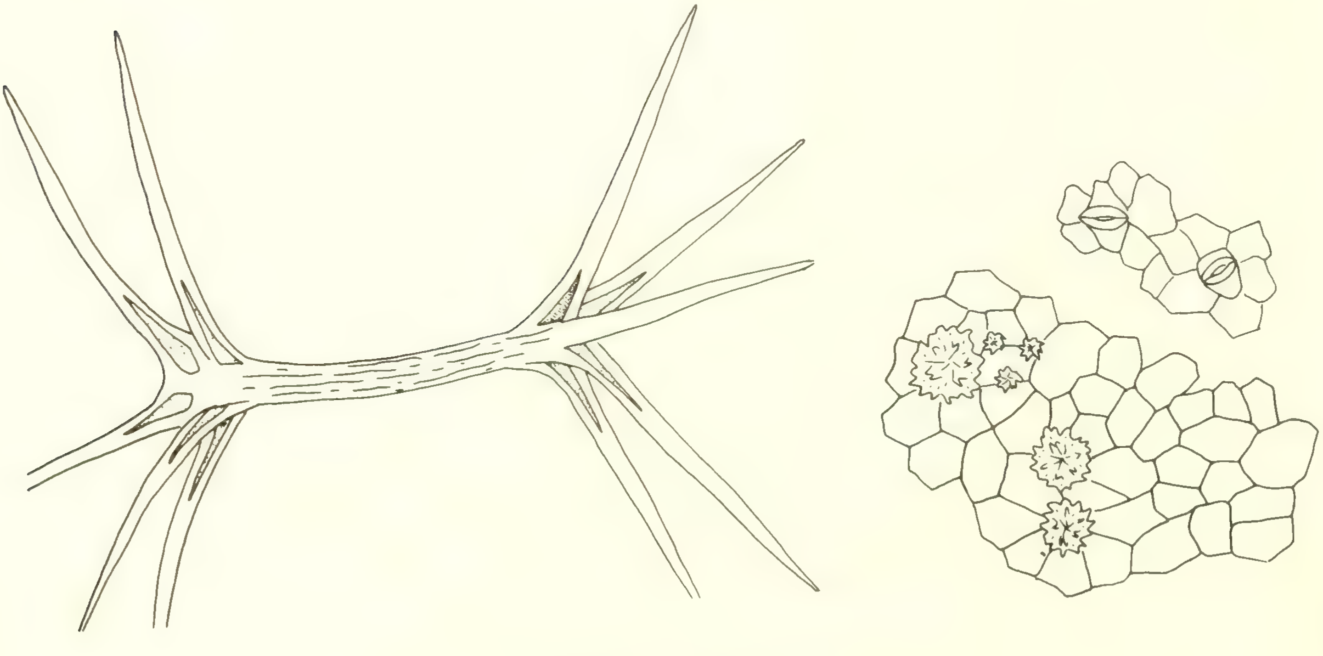
Savoryleaf aster (*Aster linariifolius*)—Short, fat segmented trichomes, and some nipple-like pappillae are present. Intercostal cells are angular and occur in layers so that cell walls overlap each other.



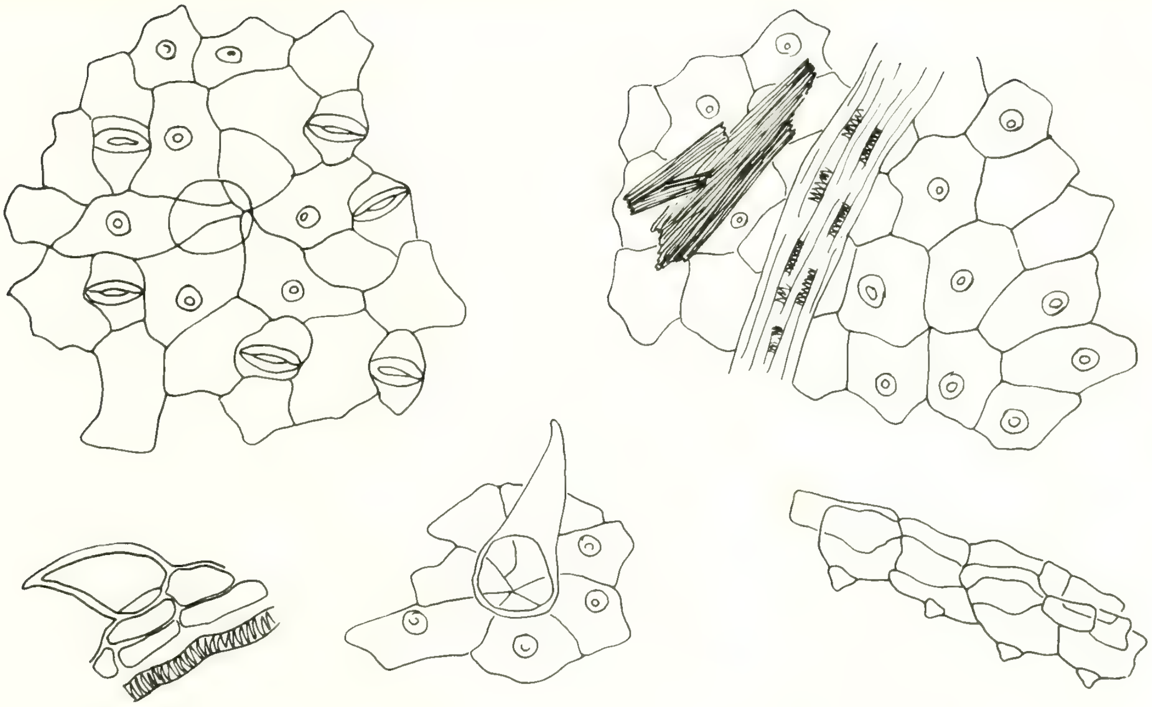
Elephantsfoot (*Elephantopus tomentosus*)—Long, tapered, thin trichomes have 2-celled bases. Puzzle-like intercostal cells contain small druses.



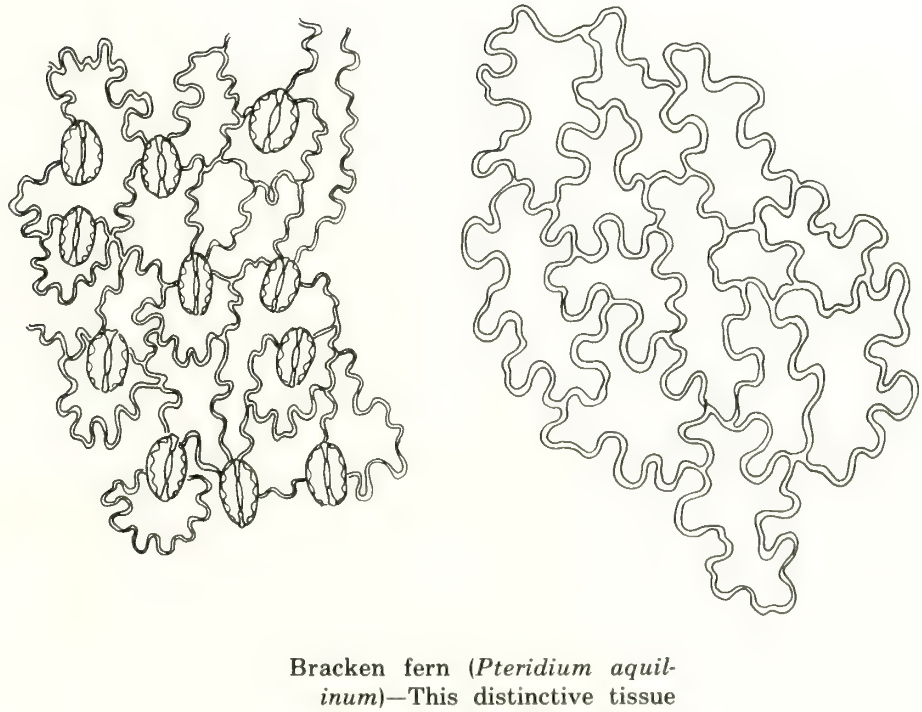
Flowering spurge (*Euphoria corollata*)—There are two types of trichomes; one is branched and similar to dogwood trichomes. Trichome attachments are surrounded by many cells.



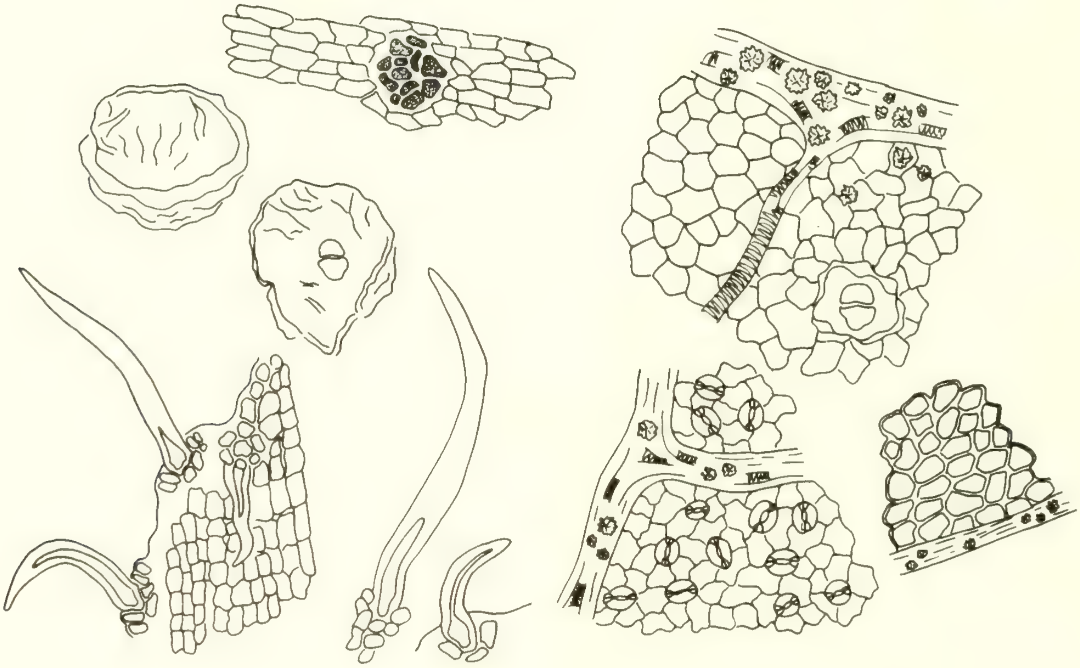
Croton (*Croton* spp.)—Compound, stellate trichomes are often attached by a common stalk. Angular cells have very thin walls so that tissues are hard to see.



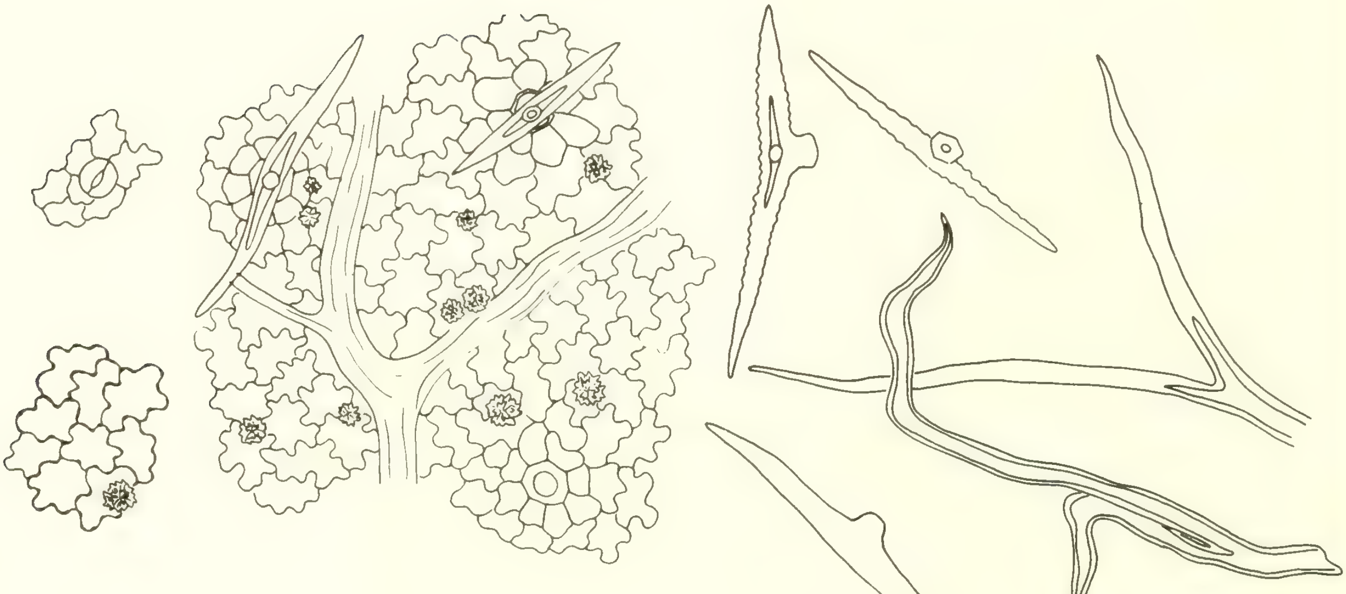
Poor-joe (*Diodia teres*)—Few trichomes occur on leaf margins. Each intercostal cell contains a nipple-like papilla. Raphides are present.



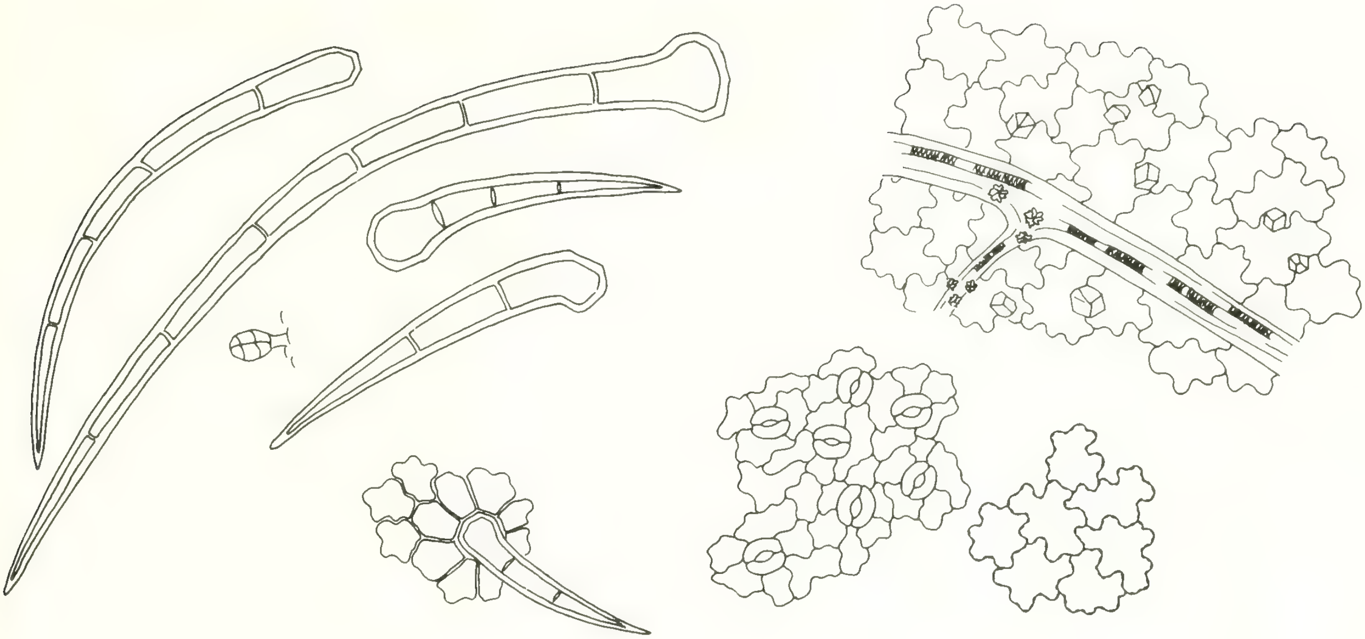
Bracken fern (*Pteridium aquilinum*)—This distinctive tissue is made of deeply lobed cells. Stomata corners have triangular cells.



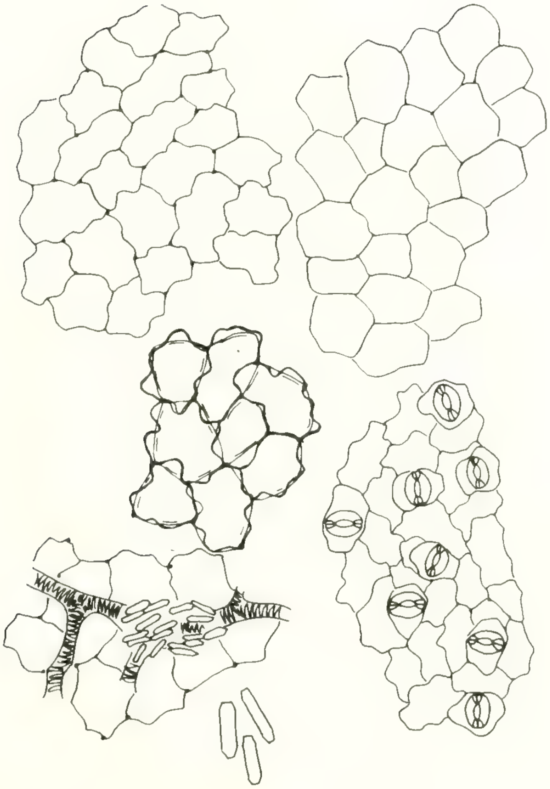
Southern waxmyrtle (*Myrica cerifera*)—Trichomes are not abundant and usually occur only on leaf margins. Druses are common.



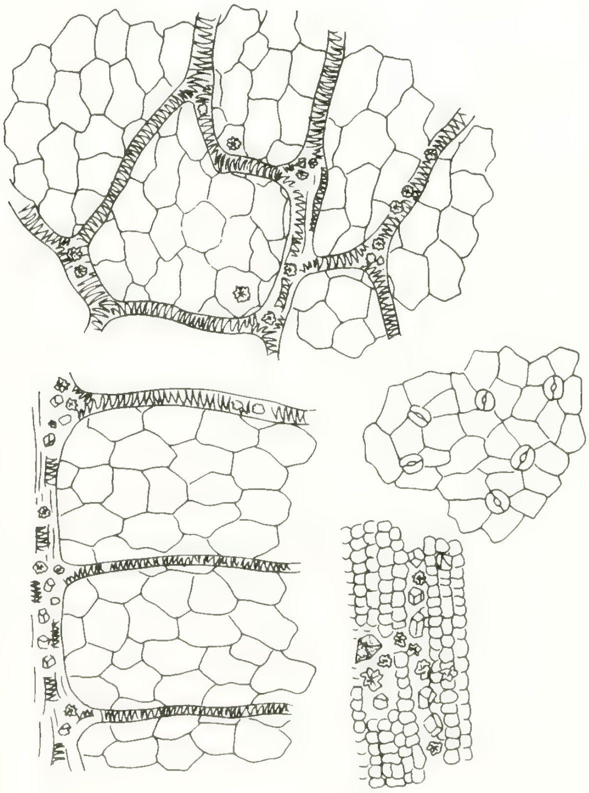
Flowering dogwood (*Cornus florida*)—Trichomes branch to form a 't' and attachment cells are mostly 8- sided. Druses are common.



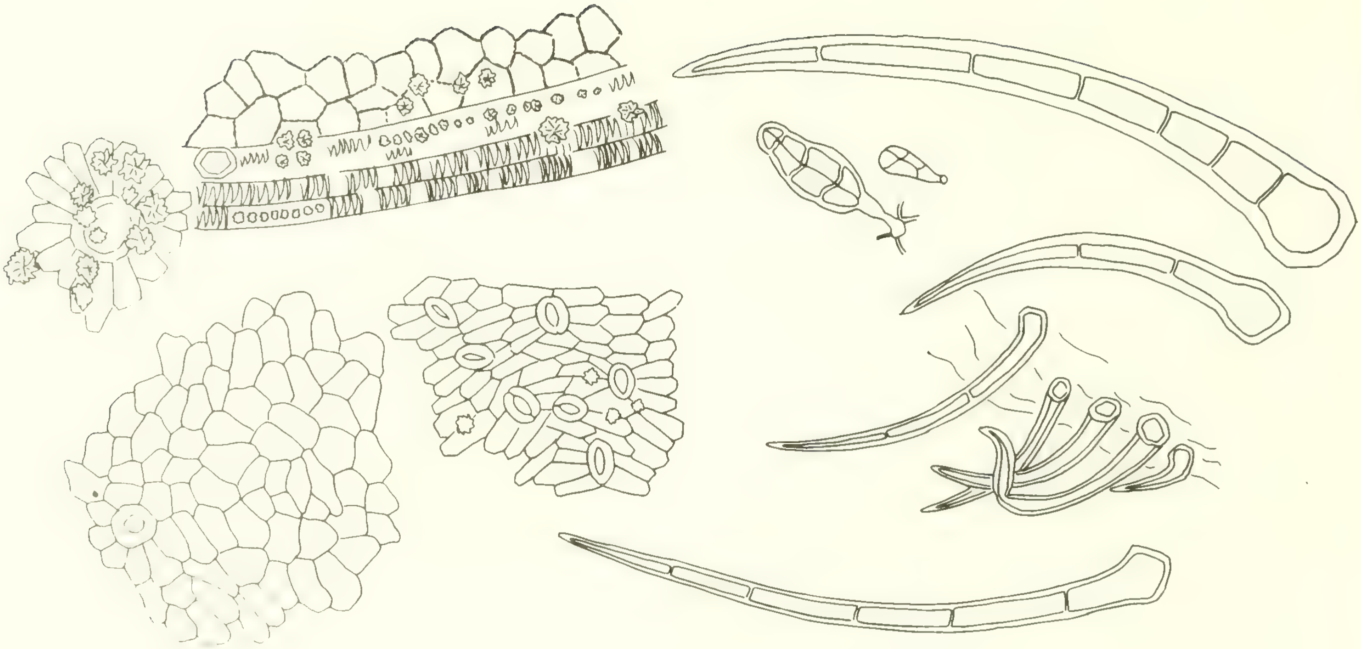
Poison ivy (*Toxicodendron radicans*)—Ligulate and glandular trichome bases are usually 6-sided. Druses occur over veins and square crystals occur between the veins.



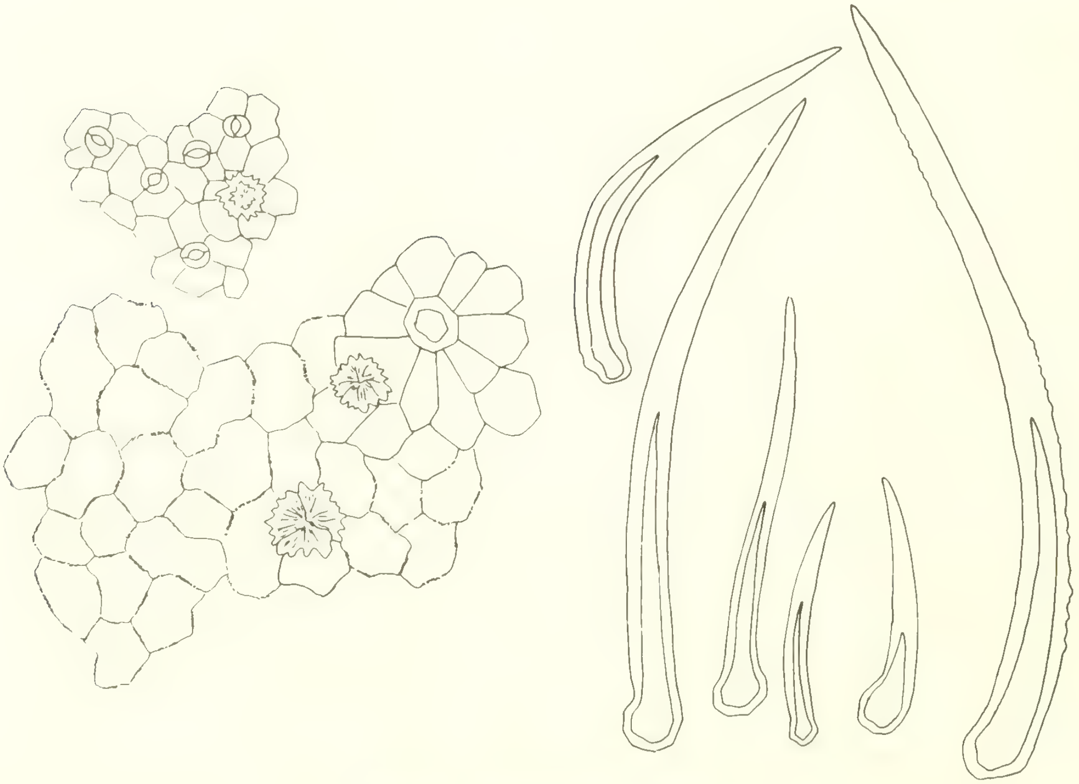
Carolina jessamine (*Gelsemium sempervirens*)—There are few trichomes so that tissues are essentially glabrous. Crystals are small and shaped like prisms.



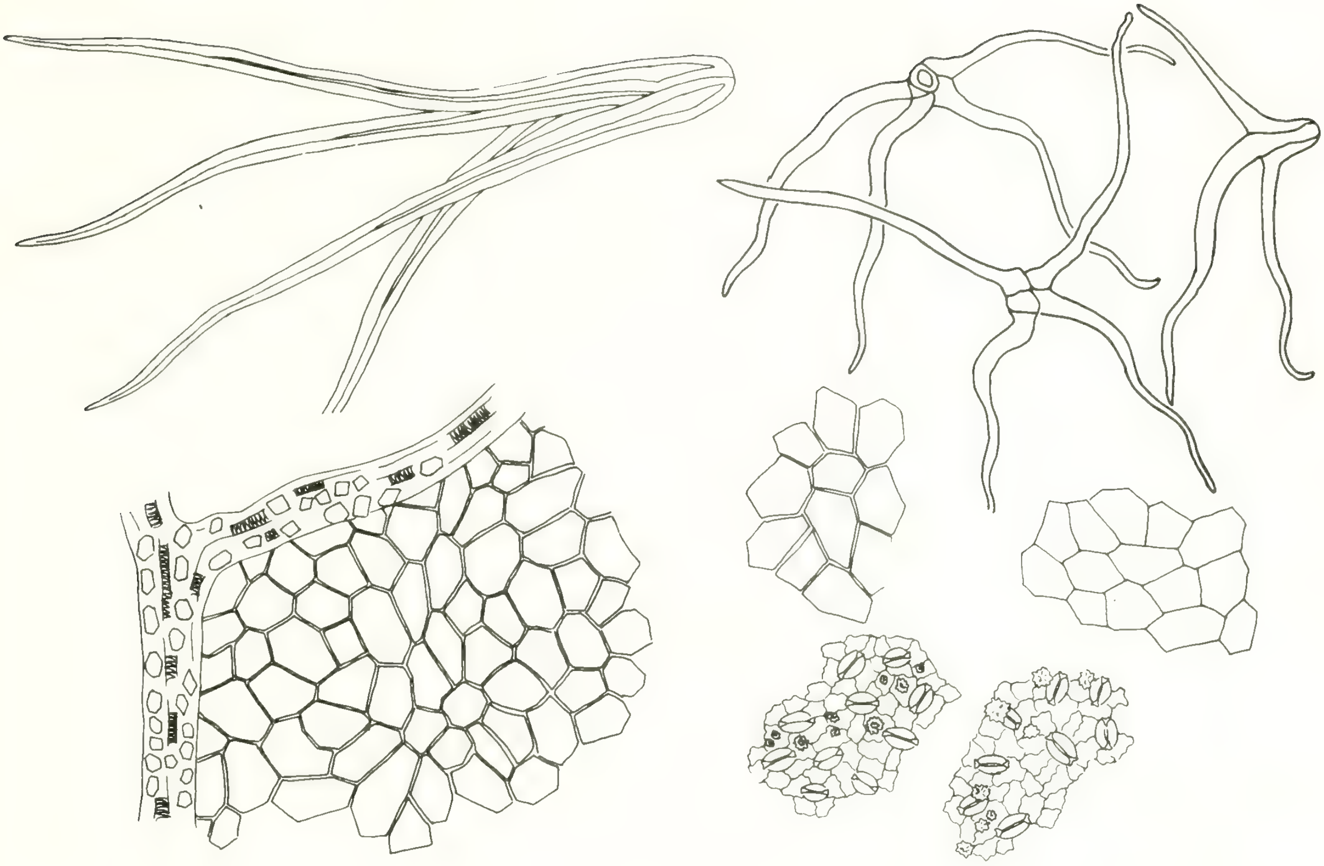
Rattanvine (*Berchemia scandens*)—There are no trichomes. Druses occur intercostally and square crystals are found over the veins. Woody tissue has small round cells and contains both types of crystals.



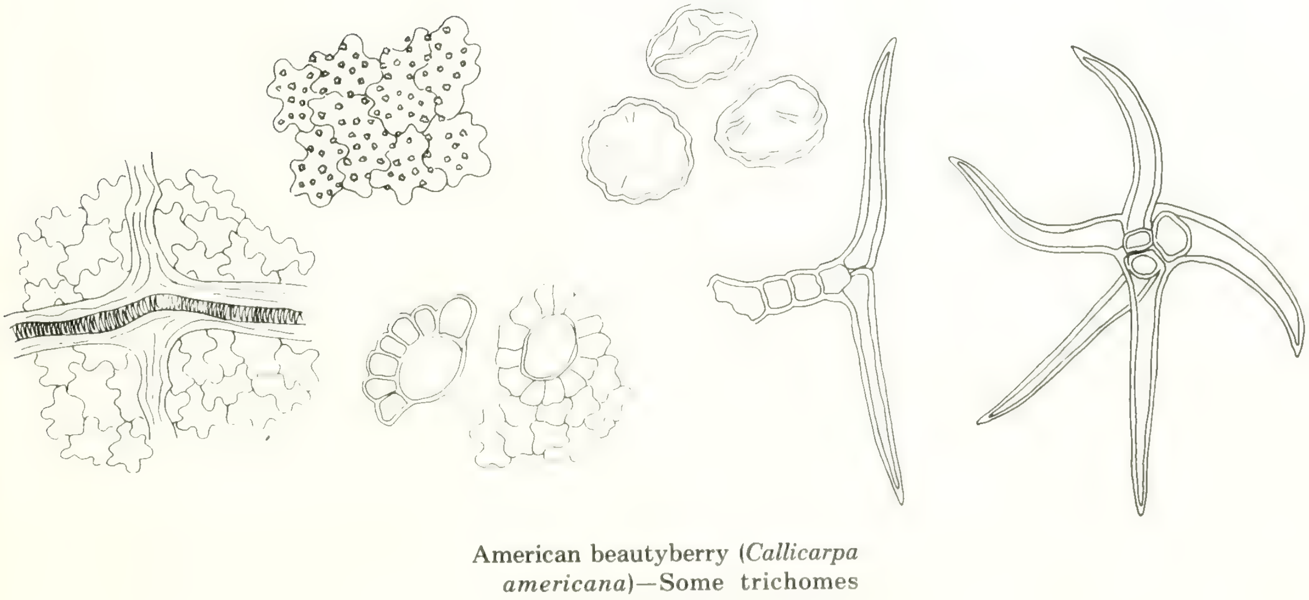
Sumac (*Rhus copallina*)—Ligulate, internally segmented trichomes have swollen bases that are usually 6-sided. Cells fit together to resemble alligator skin.



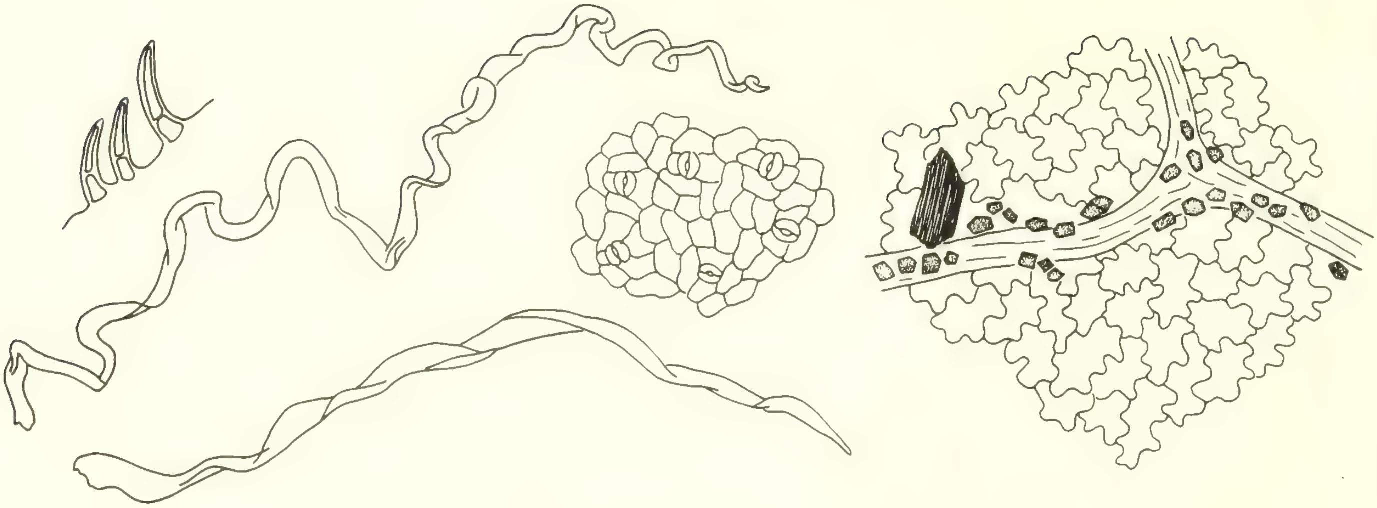
Japanese honeysuckle (*Lonicera japonica*)—Ligulate, hollow trichomes have 6-sided attachment cells. Large crystals are not abundant.



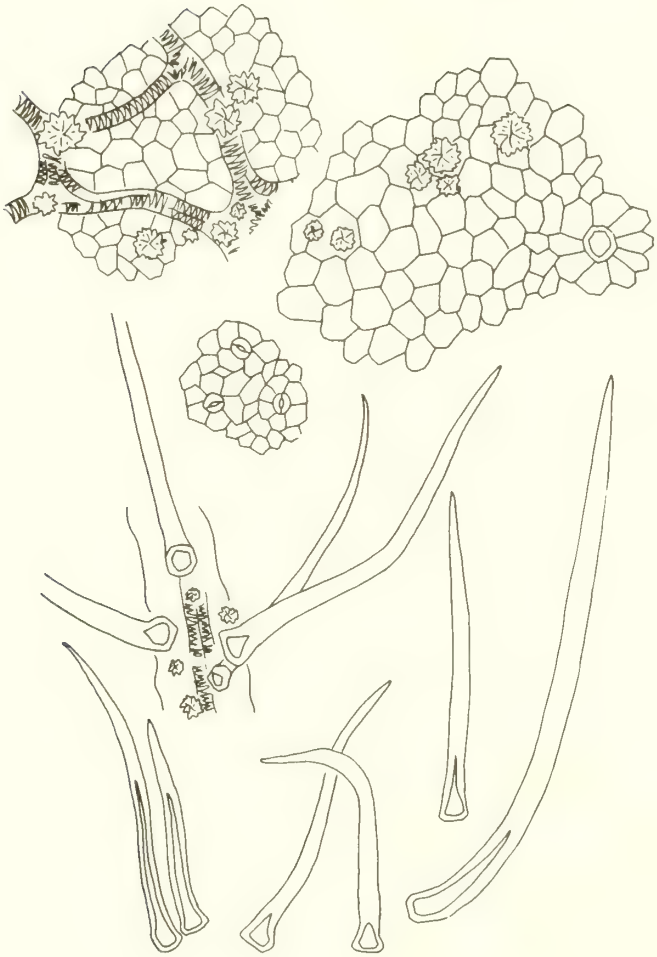
Oaks (*Quercus* spp.)—All species have compound stellate hairs that vary in size. Small druses are usually abundant. Some species have a few square crystals.



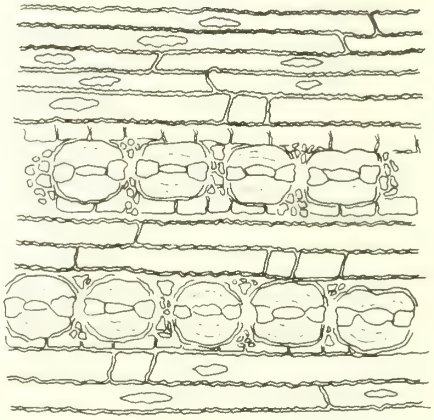
American beautyberry (*Callicarpa americana*)—Some trichomes are branched or compound but most are stellate.



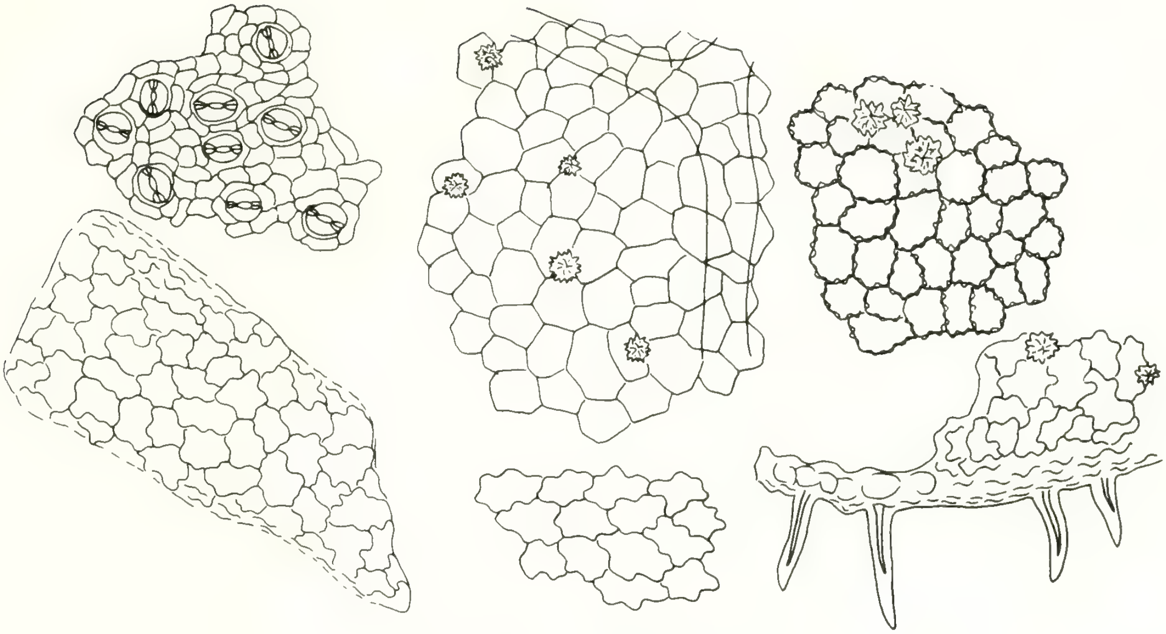
Wild grape leaves (*Vitis* spp.)—Trichomes are ribbon-like. Square crystals and druses are usually along the veins, and large raphides are present intercostally.



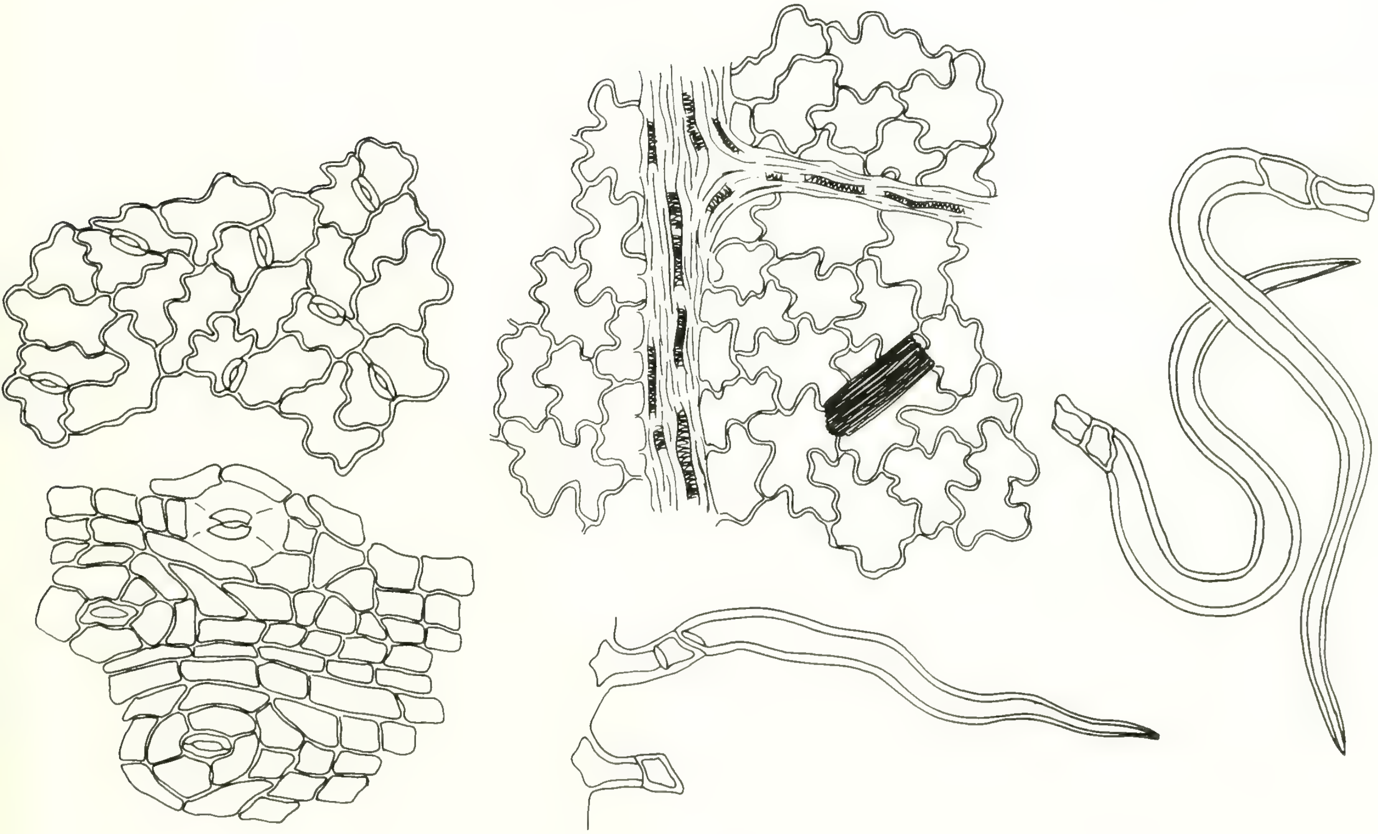
Dewberries (*Rubus* spp.)—Medium to small druses occur in tissues with angular cells. Trichomes are ligulate.



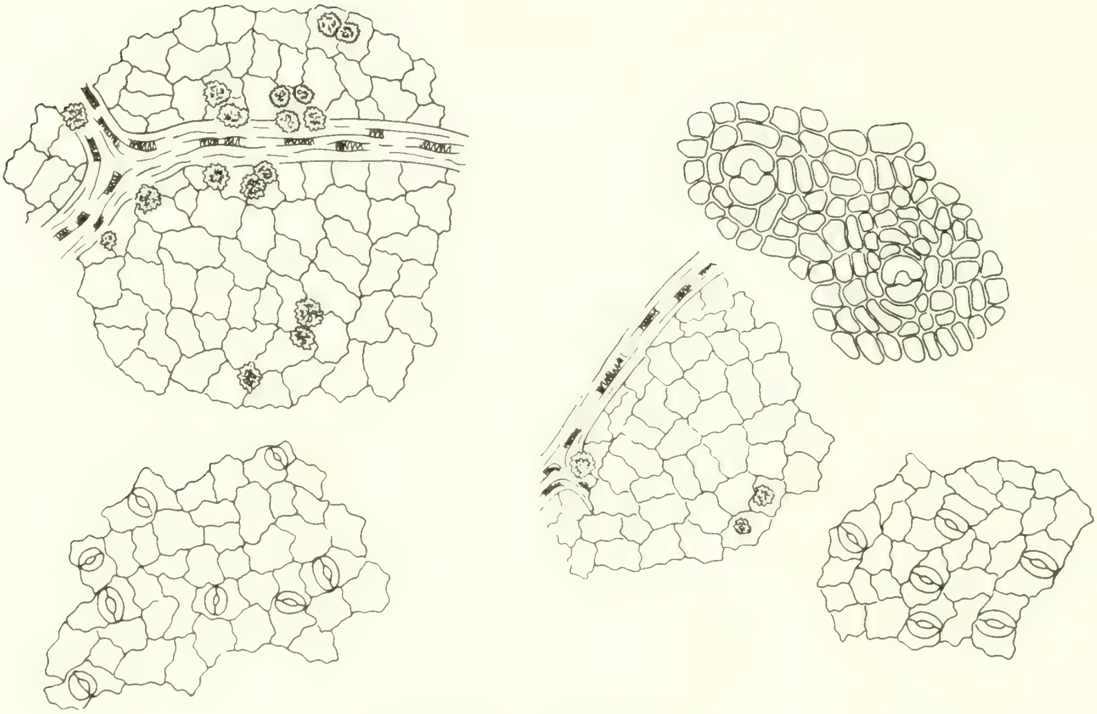
Pine (*Pinus* spp.)—Large stoma are deployed in rows with parallel intercostal cells. There are triangular cells in stoma corners.



Yaupon (*Ilex vomitoria*)—Short, ligulate trichomes are present on leaf margins, but not abundant. Medium and small druses are present.



Greenbriars (*Smilax* spp.)—*S. glauca* has small pappilae while *S. pumila* has long, ligulate trichomes with 2-celled bases. Raphides are present in both species.



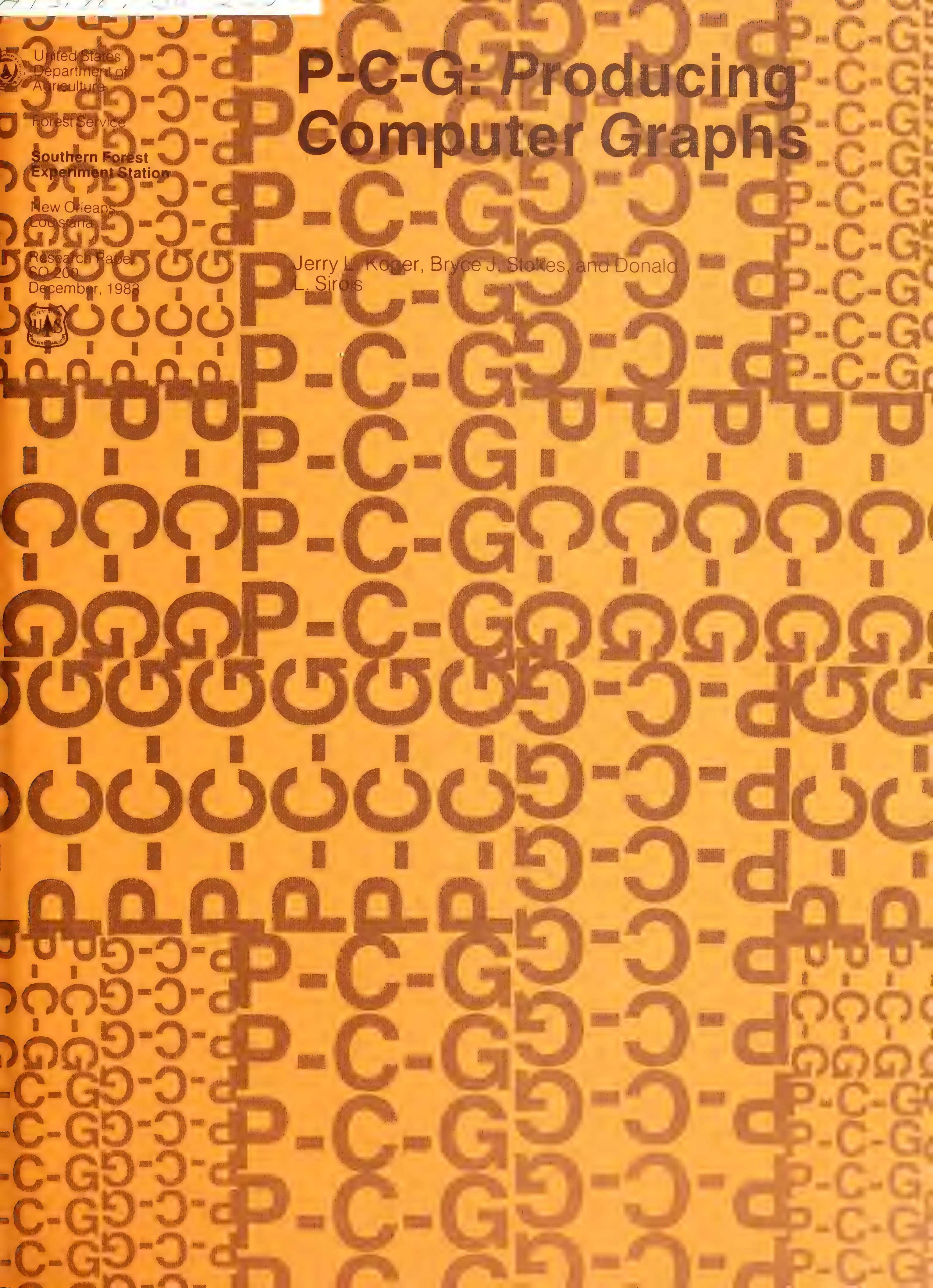
Blueberries (*Vaccinium* spp.)—Fragments are without trichomes. Druses are present intercostally with square crystals over the veins.

Johnson, Mark K.; Wofford, Helen; Pearson, Henry A. Microhistological techniques for food habits analyses. Res. Pap. SO-199. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1983. 40 p.

Techniques used to prepare and quantify herbivore diet samples for microhistological analyses are described. Plant fragments are illustrated for more than 50 selected plants common on longleaf-slash pine-bluestem range in the southeastern United States.

Keywords: Herbivore diets, plant fragments, micro-anatomy, longleaf-slash pine-bluestem range.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1984-769-089:8



United States
Department of
Agriculture

Forest Service

**Southern Forest
Experiment Station**

New Orleans,
Louisiana

Research Paper
SO-200
December, 1983

P-C-G: Producing Computer Graphs

Jerry L. Koger, Bryce J. Stokes, and Donald L. Sirois

SUMMARY

P-C-G is a computer program written in FORTRAN IV and has the capabilities of producing graphs of equations, data points, running skyline problems, surveying traverses, or user supplied programs. In addition to a graph, P-C-G produces a printed output which serves as a check of the input values and provides detailed information on intermediate program calculated values. A standard procedure or format is provided for adding specialized user written programs such as the running skyline and surveying options. Several examples are provided with the documentation to illustrate the capabilities and input requirements of P-C-G.

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P-C-G: *P*roducing *C*omputer *G*raphs

Jerry L. Koger, Bryce J. Stokes, and Donald L. Sirois

INTRODUCTION

The graphical representation of equations or data is often a practical method of understanding and explaining complex relationships. With the graphing capability of computer programs such as VERSAPLOT[1], complex graphs can be accurately and rapidly produced. However, without a standard method of organizing several equations or programs, writing the necessary FORTRAN statements required by VERSAPLOT is time consuming. P-C-G was written to provide a standard, yet flexible method of organizing equations, data, or specialized programs which can be used by VERSAPLOT to produce a graph. Although the user does not have to be familiar with VERSAPLOT, a basic knowledge of FORTRAN (McCracken 1972) is required.

PROGRAM CAPABILITIES

P-C-G is a computer program that accepts input, processes it, and produces printed output and a graph. P-C-G is capable of plotting from one to ten equations per graph with the additional options of:

1. Providing a symbol (i.e. and asterisk*) at each (x,y) data point. This option is useful when the data points used to develop a regression equation and the regression equation are to be graphed.
2. Providing additional text information on the graph other than the title, axis-labels, and equation descriptions.
3. Constructing squares, triangles, etc., which can be used to enclose text information or identify points on the graph.
4. Providing a variety of grid patterns on the graph.
5. Performing a running skyline analysis based on the equations and program developed by Carson(1975).
6. Performing a standard land surveying analysis.
7. Providing a standard format for graphing scaled or unscaled (x,y) data points, extra equations, and user written programs.
8. Providing a printout of all (optional) program calculated scaled and unscaled values.

COMPUTER COMPATIBILITY

P-C-G is written in FORTRAN IV and has been run extensively on an IBM 3031. In addition to the computer, P-C-G requires an off-line Versatec plotter with the associated library subroutines. With a modest amount of additional effort, the program can be converted for use on similar sized computer systems utilizing a VERSAPLOT (or CALCOMP) plotting package. The amount of total core storage used for a medium sized job is approximately 196K: 192K(FORT), 196K(LKED), 116K(GO), and 44K(PLOT). Normal CPU time is 0.50 minutes: 0.43(FORT), 0.04(LKED), 0.01(GO), and 0.02(PLOT).

PROGRAM AVAILABILITY

A punched and interpreted source deck (1657 cards) of P-C-G can be obtained from: Engineering Research Unit, G. W. Andrews Forestry Sciences Laboratory, U.S. Forest Service, Devall Street, Auburn University, Alabama 36849. Phone: (205) 887-7542, (FTS) 534-4518.

P-C-G GRAPHING CONVENTIONS

The VERSAPLOT plotting software operates under the concept of a basic planar two dimensional Cartesian coordinate system. Depending on the type of plotter and installations limits, graphs can be pro-

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[1] The use of trade or corporate names is for reader association and convenience. Such use does not constitute an official evaluation, conclusion, recommendation, endorsement, or approval of any product or service to the exclusion of others which may be suitable.

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duced having an x-axis length of several feet and a y-axis height of 10 inches. Although VERSAPLOT contains several subroutines, P-C-G only uses: PLOTS, PLOT, NEWPEN, SYMBOL, LINE, and GRID.

P-C-G does not calculate scale values, except as an option in the surveying program. The scales must be calculated and supplied as part of the input requirements. The scale for each axis must be expressed as the number of units (feet, meters, kilograms, days, etc.) per inch of graph. This is calculated separately for each axis (x and y) as:

$$\text{Scale} = \frac{\text{maximum axis value} - \text{minimum axis value}}{\text{axis length (in inches)}}$$

For example, if the minimum x value was 53.6 and the maximum x value was 289.0, then the x-axis scale would be 47.08 units per graph inch (i.e. (289.0 – 53.6)/5.0). Although this value could be used, it would cause the graph's x-axis to be in unhandy multiples. In order to obtain a more readable graph, the scale should be increased from 47.08 to 50.

P-C-G does not calculate the x-axis and y-axis values placed opposite each major tic mark. The user must supply these values, which are based on either the actual or adjusted scale, as part of the input requirements. In the above example, the values for the major tic marks on the x-axis would be: 50.0, 100.0, 150.0, 200.0, 250.0, and 300.0. Each value requires a separate card. In the surveying option, the x and y axis values are usually not needed and can be omitted.

P-C-G allows for a maximum of 50 points (x,y) per equation or 50 sides in a survey traverse. The appropriate DIMENSION statements must be changed if more points are to be plotted. For example, if 500 points are to be plotted per equation or traverse, then the appropriate DIMENSION statements would have to be increased to 502. The extra two spaces are needed for SUBROUTINE LINE.

The input unit for the READ statement is 5 and the output unit for the WRITE statement is 6. These units can be changed in the source deck (near the beginning, below the DIMENSION statements) through the variables KR and KW.

The default value for the basic plotting unit of pen movement is in inches (i.e. UNITS = 1.0). Although the user can change to pen movements in feet, yards, millimeters, centimeters, or meters, the unit of pen movement for P-C-G is in inches. This refers only to pen movement and does not mean that graphs with metric units can not be produced. The user should be cautious when changing to non-inch units and understand the effect this has on all pen movements and graph size.

INSERTING EQUATIONS AND PROGRAMS

Equations must be expressed in FORTRAN and inserted at specific locations within the program (Appendices 1 & 2). If data points are to be connected by lines, but there are no equations, then READ (and FORMAT) statements can be used. These statements must be inserted at specific locations within the program. The procedures for inserting equations or READ statements are described in more detail in the documentation (Appendix 2).

P-C-G was also written to facilitate the graphing of numerical results from user supplied programs. For example, two programs have already been incorporated into the framework of P-C-G. These two programs (running skyline and land surveying) were added because of their frequent use at the Auburn lab. P-C-G users familar with FORTRAN will be able to add their own programs by following these two examples. The card types referred to in the following discussion of these programs are described in more detail in the documentation (Appendix 2).

Running Skyline Program

The running skyline program used in P-C-G was originally written in BASIC by Ward Carson (1975). Carson's program was converted to FORTRAN and can be accessed by Card type 16a (IEQN = 11). Card types 16b(1) and 16b(2) are used to provide information on the heights of the headspar, tailhold, ground slope and log weight. If the non-standard graph option is used, then YORG in card type 7a should have a minimum value of 3.0. Logs may be dragged or lifted free of the ground. By using a READ statement, the ground profile can also be plotted (Appendix 8).

P-C-G requires that the headspar be located (graphically) to the left of the tailhold. The projected trajectory of the carriage is calculated as the load is moved to discrete points between the headspar and tailhold.

Although 10 separate running skyline problems could be analyzed per graph, they would probably overlap and look messy. Normally, only one skyline problem should be used per graph. The information provided below the x-axis on the graph is for the first option of the first skyline problem analyzed. However, the printed output gives detailed information on all the running skyline problems.

Surveying Program

The surveying program provides a graph of the traverse (Appendix 9) and the printed output provides detailed information on latitudes and departures. The standard method of computing latitudes and departures, the sum of the interior angles, and error of closure were followed (Breed 1971). The surveying program is accessed by card type 16a (IEQN = 12). Card type 16c(1) is used for supplying quadrant, bearing, and distance data.

If a mathematically closed traverse is desired, then the interior angles are balanced (equal error distribution) and the sides are adjusted using the compass rule. A plot of the unbalanced and unadjusted traverse can also be obtained. This option is useful when a graphical representation of the errors (angles and distances) is needed. These options are user controlled inputs and are described in card type 16a.

The program will calculate a maximum scale for the traverse so that the plot will just fit the graph. To use this option, the value of SCALEX and SCALEY in card type 12 should be 0.0. If a user mistakenly chooses a scale which is too small (but$>$0), then the program will calculate a new scale. This necessary precaution ensures that the plot of the traverse is not larger than the graph.

Normally, card types 2 and 3 should be left blank. If card types 2 and 3 are left blank, the value of IXV, IXVN, IYV, and IYVN in card type 12 should be 00. In this case, card types 12a and 12b can be skipped (not even a blank card inserted). If the non-standard option is used, then YORG in card type 7a should have a minimum value of 3.0.

Although 10 separate traverses could be analyzed per graph, they would probably overlap and look messy. Normally, only one traverse should be analyzed per graph. The information provided below the x-axis on the graph is for the first option of the first surveying problem. However, the printed output gives detailed information on all the traverses analyzed.

EXAMPLES

Several examples illustrating input requirements, program insertion, and graphical output are given in Appendices 4 – 9. A brief description of each example is given in table 1.

Table 1.—*Examples illustrating the input requirements for P-C-G*

Figure number	Appendix	Example illustrates
3	4	x and y axis length for "standard graph", axis label placement, and pen sizes.
4	5	Regression line with "raw data" plotted.
5	6	Multiple equations and line symbols.
6	7	Origin change, negative x and y axis lines, program change in X(INREP) to obtain fractional increments of x, and two regression lines with separate symbols for their "raw" data points.
7	8	Running skyline analysis with log lifting and log dragging options, READ and FORMAT statements for plotting the ground profile, and enclosed text.
8	9	Land surveying analysis.

LITERATURE CITED

Breed, Charles B. Surveying. 3 ed. (Revised by Alexander J. Boone; Brother B. Austin Barry) John Wiley & Sons, Inc.; 1971. 495 p.

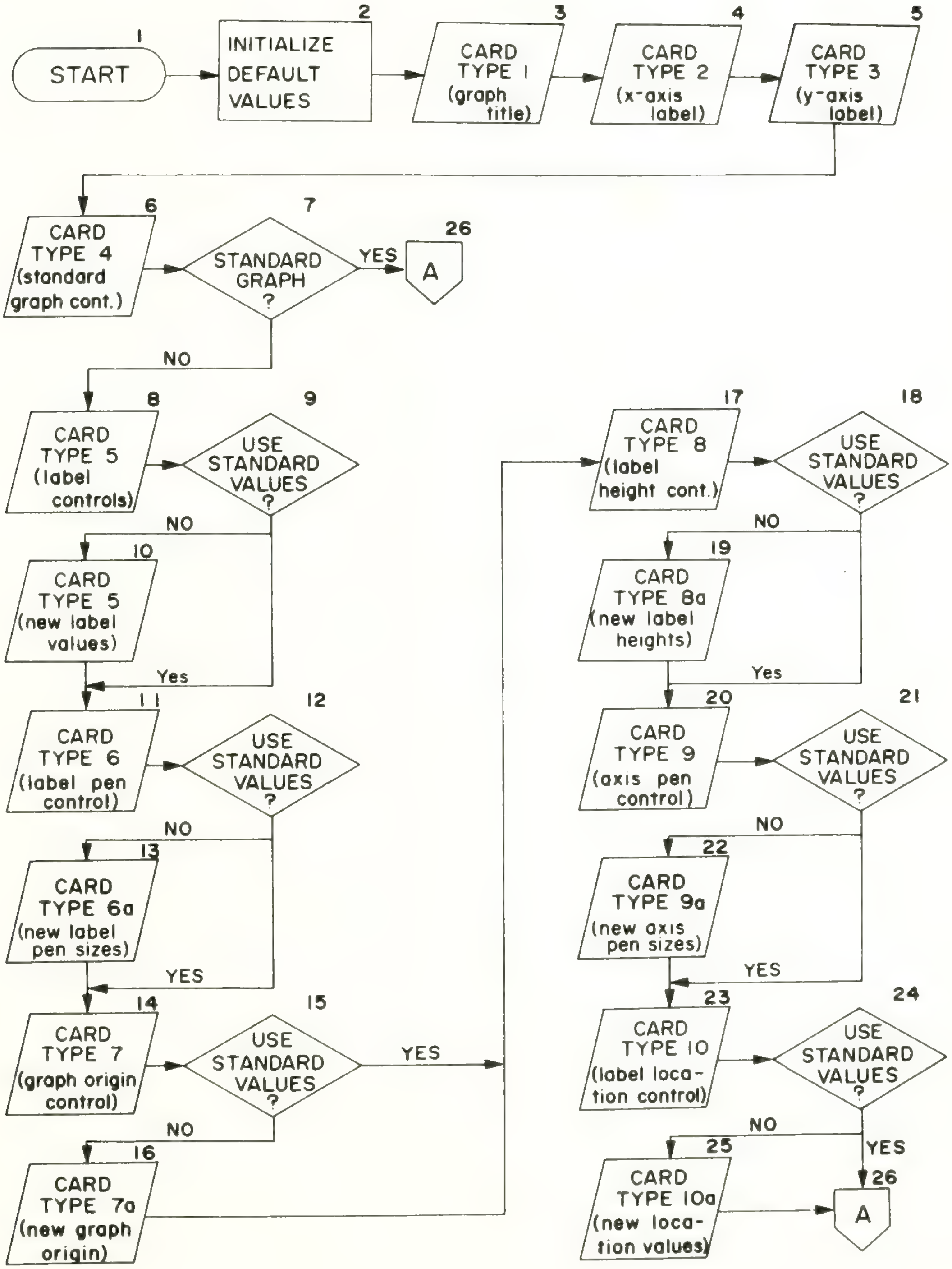
Carson, W. Ward. Programs for skyline planning. U.S. Department of Agriculture, Forest and Range Experiment Station, General Technical Report; Paper No. PNW-31; 1975. 40 p.

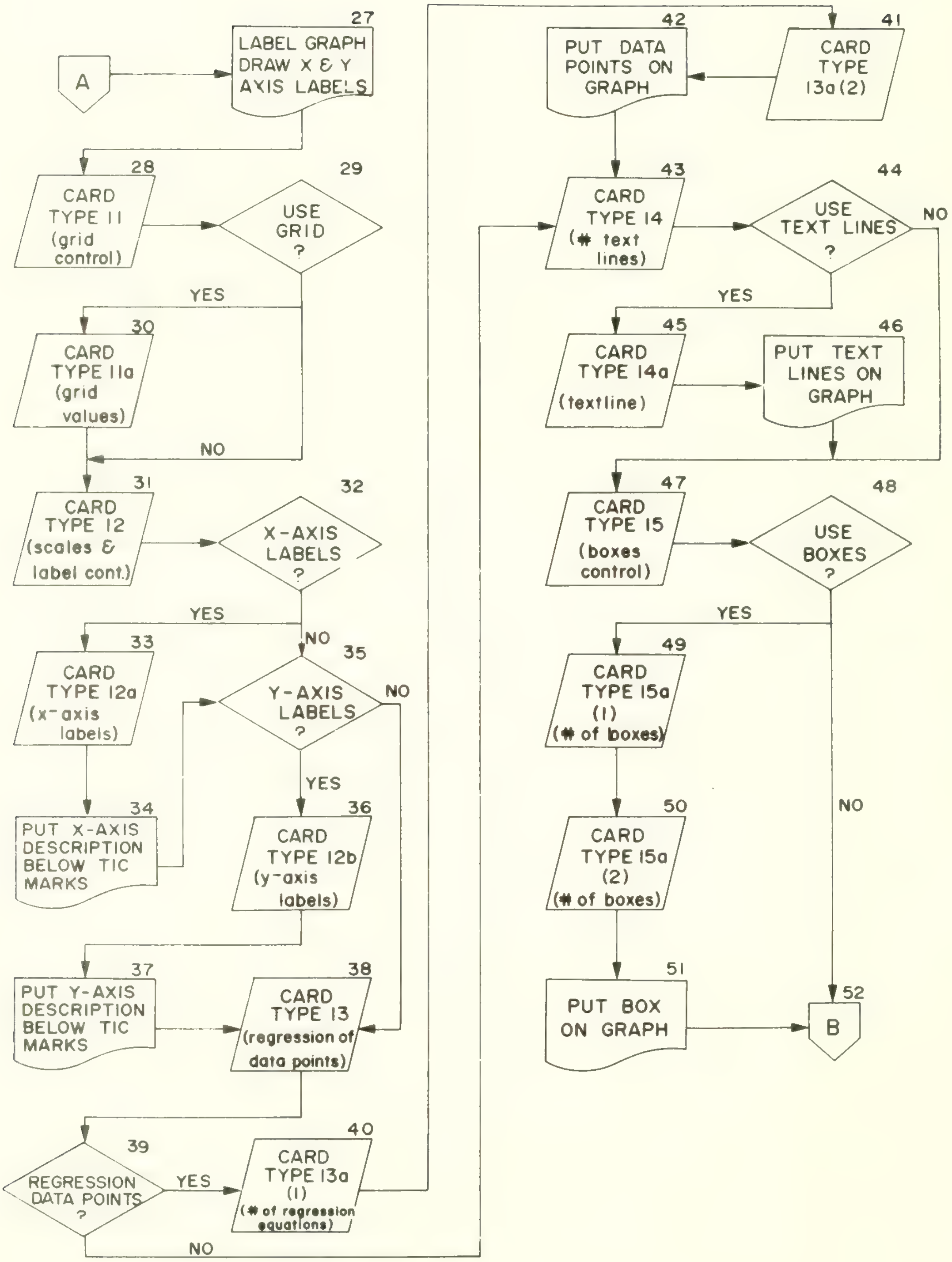
McCracken, Daniel. A guide to FORTRAN IV programming. 2 ed. John Wiley & Sons, Inc.; 1972. 288 p.

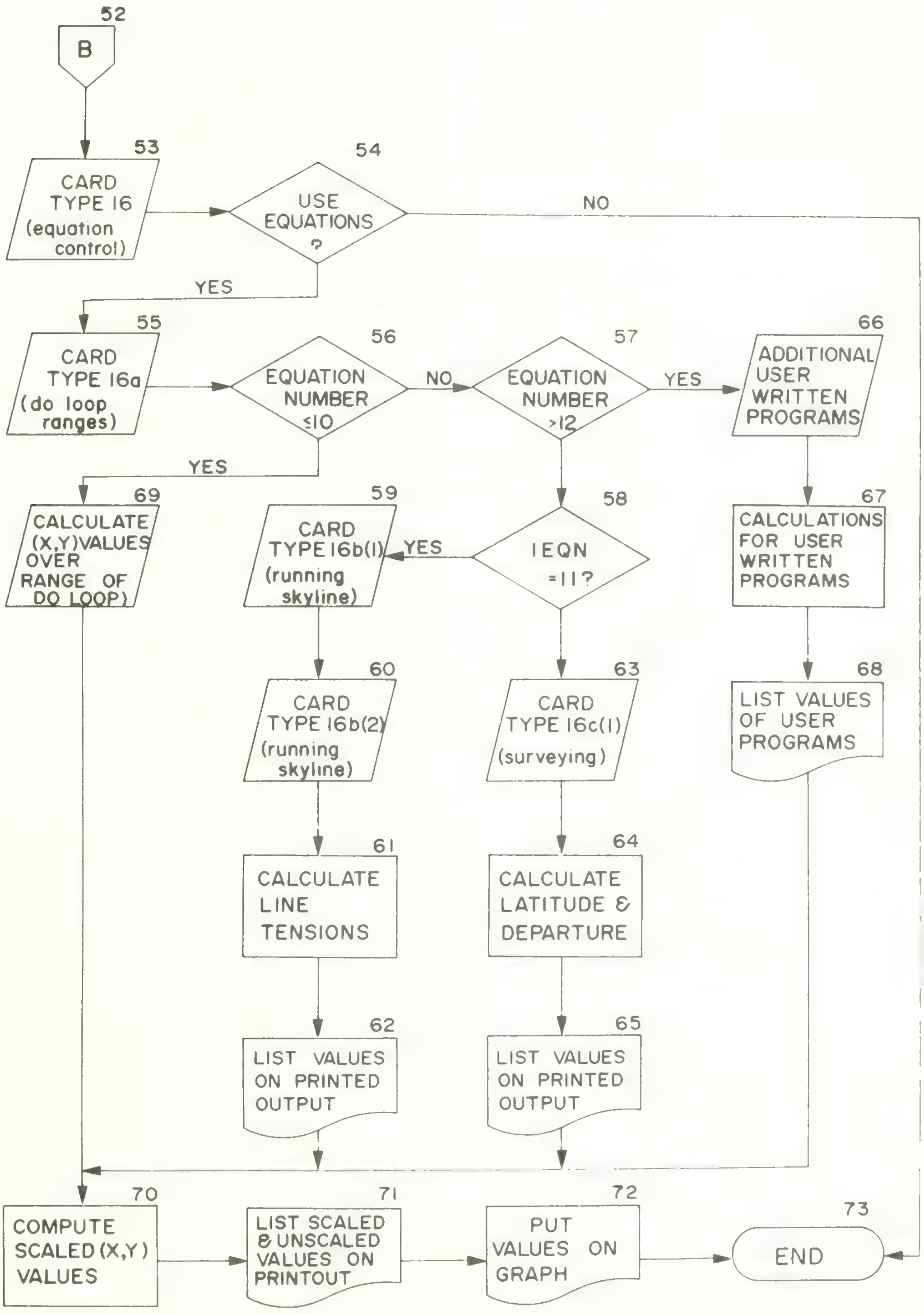
VERSAPLOT-07. Graphics programming manual (50028-90001). Xerox Company; 1976; Santa Clara, CA: Section No. 1-3.15. Appen.

Appendix 1—P-C-G Macro Flow Chart

Figure 1


1
START
2
INITIALIZE DEFAULT VALUES
3
CARD TYPE 1 (graph title)
4
CARD TYPE 2 (x-axis label)
5
CARD TYPE 3 (y-axis label)
6
CARD TYPE 4 (standard graph cont.)
7
STANDARD GRAPH ?
YES
26
A
NO
8
CARD TYPE 5 (label controls)
9
USE STANDARD VALUES ?
NO
10
CARD TYPE 5 (new label values)
Yes
11
CARD TYPE 6 (label pen control)
12
USE STANDARD VALUES ?
NO
13
CARD TYPE 6a (new label pen sizes)
YES
14
CARD TYPE 7 (graph origin control)
15
USE STANDARD VALUES ?
YES
NO
16
CARD TYPE 7a (new graph origin)
17
CARD TYPE 8 (label height cont.)
18
USE STANDARD VALUES ?
NO
19
CARD TYPE 8a (new label heights)
Yes
20
CARD TYPE 9 (axis pen control)
21
USE STANDARD VALUES ?
NO
22
CARD TYPE 9a (new axis pen sizes)
YES
23
CARD TYPE 10 (label location control)
24
USE STANDARD VALUES ?
NO
YES
25
CARD TYPE 10a (new location values)
26
A


A
27
LABEL GRAPH DRAW X & Y AXIS LABELS
28
CARD TYPE 11 (grid control)
29
USE GRID ?
YES
30
CARD TYPE 11a (grid values)
NO
31
CARD TYPE 12 (scales & label cont.)
32
X-AXIS LABELS ?
YES
33
CARD TYPE 12a (x-axis labels)
34
PUT X-AXIS DESCRIPTION BELOW TIC MARKS
NO
35
Y-AXIS LABELS ?
NO
YES
36
CARD TYPE 12b (y-axis labels)
37
PUT Y-AXIS DESCRIPTION BELOW TIC MARKS
38
CARD TYPE 13 (regression of data points)
39
REGRESSION DATA POINTS ?
YES
40
CARD TYPE 13a (1) (# of regression equations)
NO
41
CARD TYPE 13a (2)
42
PUT DATA POINTS ON GRAPH
43
CARD TYPE 14 (# text lines)
44
USE TEXT LINES ?
NO
YES
45
CARD TYPE 14a (textline)
46
PUT TEXT LINES ON GRAPH
47
CARD TYPE 15 (boxes control)
48
USE BOXES ?
YES
49
CARD TYPE 15a (1) (# of boxes)
50
CARD TYPE 15a (2) (# of boxes)
51
PUT BOX ON GRAPH
NO
52
B


52
B
53
CARD TYPE 16 (equation control)
54
USE EQUATIONS ?
NO
YES
55
CARD TYPE 16a (do loop ranges)
56
EQUATION NUMBER ≤10
NO
57
EQUATION NUMBER >12
YES
66
ADDITIONAL USER WRITTEN PROGRAMS
YES
69
CALCULATE (X,Y) VALUES OVER RANGE OF DO LOOP)
59
CARD TYPE 16b(1) (running skyline)
YES
58
IEQN =11?
67
CALCULATIONS FOR USER WRITTEN PROGRAMS
60
CARD TYPE 16b(2) (running skyline)
63
CARD TYPE 16c(1) (surveying)
68
LIST VALUES OF USER PROGRAMS
61
CALCULATE LINE TENSIONS
64
CALCULATE LATITUDE & DEPARTURE
62
LIST VALUES ON PRINTED OUTPUT
65
LIST VALUES ON PRINTED OUTPUT
70
COMPUTE SCALED (X,Y) VALUES
71
LIST SCALED & UNSCALED VALUES ON PRINTOUT
72
PUT VALUES ON GRAPH
73
END

Appendix 2—Program Documentation

The user must supply data cards at the end of the program. In addition, each equation or READ (and FORMAT) statement must be inserted at a specified location (TSO line or card number) in the program. As a result of "built in" default values (table 2), not all of the following data card types are required. Indented card types are optional and are only used to override the default values. If the standard default values are to be used, then card types 5 thru 10a must be omitted (skipped, not even a blank card inserted). However, if any of the default values are to be changed, then card types 5-10 must be answered along with the appropriate card types 5a thru 10a. The use of data card types with subscripted letters (i.e. 5a, 13a(1), 16a) depends on the preceding value of the non-subscripted card type (i.e. 5, 13, 16). The differences between card types subscripted with a letter (i.e. 5a) and those subscripted with a letter and a number in parentheses (i.e. 13a(1)) are the number of cards required and their input order. The order and purpose of each data card type are shown in table 3.

Table 2.--Default values used in P-C-G

Graph Item	Default Value
(x,y) coordinates of user graph origin	(1.2,3.0)*
(x,y) starting coordinates of graph title	(0.0,0.0)
(x,y) starting coordinates of x-axis label	(0.0,-0.3)
(x,y) starting coordinates of y-axis label	(-0.7,0.0)
pen size for graph title	4
pen size for x-axis label	3
pen size for y-axis label	3
height of title letters	0.14
height of x-axis label	0.12
height of y-axis label	0.12
height of numbers below x-axis tic marks	0.10
height of numbers opposite y-axis tic marks	0.10
height of equation labels(if any)	0.08
number of x-axis tic mark descriptions	6
number of y-axis tic mark descriptions	6
x-axis length	5
y-axis length	5
distance between major tic marks	1.00

* (1.2,3.0) is with respect to the plotting paper; all dimensions are in inches

Table 3.--Data card type and purpose

Card Type (CT)	Card Required ?	Number Required	Card Purpose
1	Yes (even if blank)	1	graph title
2	Yes (even if blank)	1	x-axis label
3	Yes (even if blank)	1	y-axis label
4	Yes (value: 0 or 1)	1	default control
5	Yes (value: 0 or 1)	1	default control
5a	Only if CT5=1	0 or 1	change label (x,y)
6	Yes (value: 0 or 1)	1	default control
6a	Only if CT6=1	0 or 1	pen label sizes
7	Yes (value: 0 or 1)	1	default control
7a	Only if CT7=1	0 or 1	graph origin
8	Yes (value: 0 or 1)	1	default control
8a	Only if CT8=1	0 or 1	label heights
9	Yes (value: 0 or 1)	1	default control
9a	Only if CT9=1	0 or 1	pen axis sizes
10	Yes (value: 0 or 1)	1	default control
10a	Only if CT10=1	0 or 1	(x,y) axis descr.
11	Yes (value: 0 or 1)	1	default control
11a	Only if CT11=1	0 or 1	grid pattern
12	Yes	1	scales, etc.
12a	*	6 (normally)	x-axis descriptions
12b	*	6 (normally)	y-axis descriptions
13	Yes	1	# regression eqs.
13a(1)	Only if CT13 > 0	1/equation	equation #,etc.
13a(2)	Only if CT13 > 0	1/data point	(x,y) of data point
14	Yes	1	# of text lines
14a	Only if CT14 > 0	1/text line	text description
15	Yes	1	# of boxes, etc.
15a(1)	Only if CT15 > 0	1/area	# of (x,y) points
15a(2)	Only if CT15 > 0	1/# points	define area
16	Yes	1	number of equations
16a	Yes if CT16 > 0	1/equation	equation description
16b(1)	Only for Skyline option	1/analysis	headspar,tailhold,etc.
16b(2)	Only for Skyline option	1/analysis	line weights,friction
16c(1)	Only for Surveying opt.	1/side	bearings & distances

* (Optional) : One card is required for each description placed opposite the big tic marks and one card is required for the origin description.

1. Card type 1: (required even if left blank)

```
 1               60cc
/_/_/_/_/_____/_/_/    TITLE   The title of the graph. For centering
                               purposes the title does not have
                               to start in card column 1.
```

2. Card type 2: (required even if left blank)

```
 1                60 cc
/_/_/_/_/____/_/_/_/   XAXIS   The label to be placed below the
                               x-axis.  For centering purposes
                               the label does not have to start
                               in card column 1. This is usually
                               left blank when using the surveying
                               option.
```

3. Card type 3: (required even if left blank)

```
 1                60 cc
/_/_/_/_/____/_/_/_/   YAXIS   The label to be placed opposite
                               the y-axis.  For centering
                               purposes the label does not have
                               to start in card column 1. This
                               is usually left blank when
                               using the surveying option.
```

4 Card type 4: (required; Value of 0 or 1)

```
 1 cc
/_/                    IQKADT  = 0 if the default values are not
                               to be changed.  If a 0 is coded in
                               card column 1, then skip to card
                               type 11.
                               = 1 if any of the default values
                               are to be changed.  If a 1 is coded
                               in card column 1, then card types
                               5-10 must be answered along with
                               5a-10a where appropriate.
```

5. Card type 5: (required only if card type 4 = 1)

```
 1 cc
/_/                    ICHNGC  = 0 if the default values for the
                               coordinates of the title, x-axis,
                               and y-axis labels  are to be used.
                               = 1 if changes in any of these values
                               are to be made.
```

5a. Card type 5a: (required only if card type 5 = 1)

```
 1    4   6 cc
/_/_/_/./_/_/          XCT     The x coordinate of the graph title
                               (default = 0.0).
 7     10  12 cc
/_/_/_/./_/_/          YCT     The y coordinate of the graph title
                               (default = 6.0).
```

13 16 18 cc /_/_/_/._/_/_/	XCX	The x coordinate of the x-axis label (default = 0.0).
19 22 24 cc /_/_/_/./_/_/	YCX	The y coordinate of the x-axis label (default = -0.5).
25 28 30 cc /_/_/_/./_/_/	YXC	The x coordinate of the y-axis label (default = -0.7).
31 34 36 cc /_/_/_/./_/_/	YYC	The y coordinate of the y-axis label (default = 0.0).
		Note: The above (x,y) coordinates are the starting coordinates of the A FORMAT used in printing the labels.

6. Card type 6: (required only if card type 4 = 1)

1 cc /_/	IPENCT	= 0 if the standard pen sizes for the title, x-axis, and y-axis labels are to be used. = 1 if changes in the default values are to be made.

6a. Card type 6a: (required only if card type 6 = 1)

1 cc /_/	IPENT	The pen size (1-5) used in drawing the title (default = 4).
2 cc /_/	IPENXA	The pen size (1-5) used in drawing the x-axis label (default = 3).
3 cc /_/	IPENYA	The pen size used in drawing the the y-axis label (default = 3).

7. Card type 7: (required only if card type 4 = 1)

1 cc /_/	IORGIN	= 0 if the standard (x,y) coordinates for the axis intersection or graph origin are to be used. = 1 if changes in the default values are to be made.

7a. Card type 7a: (required only if card type 7 = 1)

1 4 7 cc /_/_/_/./_/_/_/	XORG	The x coordinate of the axis intersection with respect to the standard used by the plotting software (default = 1.2).

8 11 14 cc /_/_/_/./_/_/_/	YORG	The y coordinate of the axis intersection or graph origin with respect to the standard used by the plotting software (default = 3.0).

8. Card type 8: (required only if card type 4 = 1)

1 cc /_/	ITXYHT	= 0 if the standard heights are to be used in the title, x-axis labels and numbers, y-axis labels and numbers, and equation labels (if any). = 1 if changes in the default values are to be made.

8a. Card type 8a: (required only if card type 8 = 1)

1 4 cc /_/./_/_/	HTT	The height of the letters or symbols used in the title (default = 0.14). Note: height and width are related.
5 8 cc /_/./_/_/	HTXT	The height of the letters or symbols used in the x-axis label (default = 0.12).
9 12 cc /_/./_/_/	HTYT	The height of the letters or symbols used in the y-axis label (default = 0.12).
13 16 cc /_/./_/_/	HTXN	The height of the numbers or symbols used as unit descriptions below each major tic mark on the x-axis (default = 0.10).
17 20 cc /_/./_/_/	HTYN	The height of the numbers or symbols used as unit descriptions opposite each major tic mark on the y-axis (default = 0.10).
21 24 cc /_/./_/_/	HTEQL	The height of the letters of symbols used to label equations (default = 0.08).

9. Card type 9: (required only if card type 4 = 1)

1 cc /_/	IAXISL	= 0 if the standard pen sizes used to draw the axis lines and tic marks as well as the side of the axis line the tic marks are to be drawn are to be used. = 1 if changes in these default values are to be made.

9a. Card type 9a: (required only if card type 9 = 1)

1 cc /_/	IXYAT	The pen size (1-5) used to draw the x and y-axis lines (default = 4)
2 cc /_/	IBIGT	The pen size (1-5) used to draw the big tic marks (default = 3).
3 cc /_/	ILILT	The pen size (1-5) used to draw the little tic marks (default = 2).
4 cc /_/	ISIDET	= 0 if tic marks are to be drawn on the outside of the axis lines (default=0). = 1 if tic marks are to be drawn on the inside of the axis lines.
6 cc /_/_/	INXT	The number (>0) of big tic marks on the x-axis, excluding the one at the origin (default = 5).
8 cc /_/_/	INYT	The number (>0) of big tic marks on the y-axis, excluding the one at the origin (default = 5).
10 cc /_/_/	INLTPB	The number (>0) of little tic marks per big tic mark (default = 1).
11 13 15 cc /_/_/./_/_/	XAXISL	The length of the x-axis (default = 5.0).
16 18 20 cc /_/_/./_/_/	YAXISL	The length of the y-axis (default = 5.0).

10. Card type 10: (required only if card type 4 = 1)

1 cc /_/	IPLDFA	= 0 if the default values for the starting positions of the x and y-axis unit descriptions and their distance from the axis lines are to be used. = 1 if changes in these default values are to be made.

10a. Card type 10a: (required only if card type 10 = 1)

1 3 5 cc /_/_/./_/_/	SXCFN	The starting x coordinate for the first unit description used on the x-axis (default = 0.00)
6 8 10 cc /_/_/./_/_/	DFXA	The distance the unit descriptions are from the x-axis (default= -0.30).

11 13 15 cc /_/_/./_/_/	SYCFN	The starting y coordinate for the first unit description used on the y-axis (default = 0.00).
16 18 20 cc /_/_/./_/_/	DFYA	The distance in inches the unit descriptions are from the y-axis (default = -0.70).
21 23 25 cc /_/_/./_/_/	XSLINE	The distance the x-axis line is to start from the origin (default=0.0). This number will be negative when drawing a x axis line to the left of the origin.
26 28 30 cc /_/_/./_/_/	YSLINE	The distance the y-axis line is to start from the origin (default=0.0). This number will be negative when drawing a y-axis line below the origin.

11. Card type 11: (required; value 0 or 1)

1 cc /_/	IGRID	= 0 if a grid overlay is not used. = 1 if a grid overlay is used.

11a. Card type 11a: (required only if card type 11 = 1)

2 cc /_/_/	NXG	The number of vertical grid lines per big tic mark on the x-axis.
4 cc /_/_/	NYG	The number of horizontal grid lines per big tic mark on the y-axis.
6 cc /_/_/	IGRIDN	The grid pattern number which is used to control the size of the grid lines (suggest 08).

12. Card type 12: (required)

1 cc /_/	IWRTE	= 0 if only the last (x,y) scaled and unscaled values for each equation are to be listed on the printed output. = 1 if all the scaled and unscaled values for each equation are to be listed on the printed output.
3 cc /_/_/	IXV	The number of separate unit descriptions used below each big tic mark on the x-axis. This will normally be 06 (i.e. one for the origin plus one for each of the five big tic marks on the x-axis). This is normally 00 for the surveying option.

5 cc `/_/_/`	IXVN	This should normally be 10. It is the maximum width of the A-FORMAT used in the x-axis descriptions. This is normally 00 for the surveying option.
7 cc `/_/_/`	IYV	The number of separate unit descriptions used opposite each big tic mark on the y-axis. This will normally be 06 (i.e. one for the origin plus one for each of the five big tic marks on the y-axis. This will normally be 00 for the surveying option.
9 cc `/_/_/`	IYVN	This should normally be 06. It is the maximum width of the A-FORMAT used in the y-axis descriptions. This will normally be 00 for the surveying option.
10 16 19 cc `/_/_/_/_/_/_/./_/_/_/`	SCALEX	The change in x with respect to one inch along the x-axis. This is normally calculated as: (max x - min x)/(x-axis length). This value can be rounded to obtain "neater" increments on the x-axis. Although there may be several equations per graph, there is only one value for SCALEX per graph. In the surveying option, SCALEX can be given a zero (0.0) value. If given a value of 0.0, the program caluclates the largest scale that will fit on the graph.
20 26 29 cc `/_/_/_/_/_/_/./_/_/_/`	SCALEY	The change in y with respect to one inch along the y-axis. This is normally calculated as: (max y - min y)/(y-axis length). This value can rounded to obtain "neater" s on the y-axis. be several equations is only one value aph. option, SCALEY value used
30 `/_/_/_/_/_/`		t the graph origin. jin of (0.0,y.y), this
40 `/_/_/_/_/_/`		at the graph origin. igin of (x.x,0.0), this

12a. Card type 12a: (required if descriptions are placed below the big tic marks on the x-axis)

1 6 10 cc /_/_/_/_/_/_/_/_/_/_/	XAXV	The numbers or labels to be placed below the x-axis (at the origin and at each big tic mark). The number of cards required will be equal to the value of IXV in Card Type 12. A number or symbol coded in card column 6 will be printed directly below the big tic marks. This is an A FORMAT. In the surveying option, these cards are usually not required, especially if the value of SCALEX is zero.

12b. Card type 12b: (required if descriptions are placed opposite the big tic marks on the y-axis).

1 6 cc /_/_/_/_/_/_/	YAXV	The numbers or labels to be placed opposite the y-axis (at the origin and at each big tic mark). The number of cards required will be equal to the value of IYV in card type 12. The number or symbol should be right justified. This is an A FORMAT. In the surveying option, these cards are usually not required, especially if the value of SCALEX is zero.

13. Card type 13: (required; value 0 or 1)

1 cc /_/	IPLOTP	= 0 if no "raw" data points are to plotted with the regression line. = 1 if "raw" data points are to be plotted with the regression line.
2 3 cc /_/_/	INEQP	The number (00-10) of regression equations with data points plotted.

13a(1). Card type 13a(1): (required only if IPLOTP > 0 in card type 13)

2 cc /_/_/	NPTBP	The number of data points to be plotted with this equation.
3 cc /_/	ASYMBP	The symbol (i.e. *,$,etc.) used to locate the points (x,y) on the graph.

13a(2). Card type 13a(2): (required only if IPLOTP > 0 in card type 13)

1 7 10 cc /_/_/_/_/_/_/_/./_/_/_/	X(IU)	The unscaled x coordinate of the data point.

11 17 20 cc /_/_/_/_/_/_/./_/_/_/	Y(IU)	The unscaled y coordinate of the data point. One card will be required for each data point. There will be as many card type 13a(1) cards as specified by INEQP in card type 13. There will be as many card type 13a(2) cards as specified by NPTBP in card type 13a(1).

14. Card type 14: (required; value 00-20)

2 cc /_/_/	NLTEXT	The number of lines (00-20) of aditional text used on the graph.
3 5 7 cc /_/_/./_/_/	TEXTH	The height of the text lettering. If NLTEXT>0 suggest 0.08. If NLTEXT=0, then TEXTH=0.0.

14a. Card type 14a: (required only if NLTEXT > 0 in card type 14).

1 4 7 cc /_/_/_/./_/_/_/	X(IW)	The x-coordinate in actual graph inches for the beginning of the text line.
8 11 14 cc /_/_/_/./_/_/_/	Y(IW)	The y-coordinate in actual graph inches for the beginning of the text line.
15 34 c /_/_/____/_/_/	GTEXT(IX,IY)	The line of text (letters, symbols, or numbers, if any).

15. Card type 15: (required; value 00-20)

2 cc /_/_/	IAREAN	The number (00-20) of figures (triangles, etc.) or additional lines to be drawn on the graph.

15a(1). Card type 15a(1): (required only if IAREAN > 0 in card type 15)

2 cc /_/_/	IPTPAR	The number of points (x,y) for each side of the figure, plus 1. A four sided figure would require 5 points. The fifth (x,y) point must be a repetition of the first (x,y) point.

15a(2). Card type 15a(2): (required only if IAREAN > 0 in card type 15; the number of cards required depends on the value of IPTPAR in card type 15a(1))

1 7 10 cc /_/_/_/_/_/_/./_/_/_/	X(IC)	The x-coordinate of the figure.

11 17 20 cc `/_/_/_/_/_/_/_/./_/_/_/`	Y(IC)	The y-coordinate of the figure.

16. Card type 16. (required; value 00-10)

2 cc `/_/_/`	INOEQ	The number (00-10) of equations (or READ statments) to be graphed. In the running skyline and surveying options this is normally equal to 01.

16a. Card type 16a: (required if INOEQ in card type 16 is > 0).

2 cc `/_/_/`	IEQN	The equation number. Equation numbers 01-10 require the user to make changes in the main program (discussed later). = 11 for running skyline program = 12 for surveying program
3 5 cc `/_/_/_/`	ILINET	= 0 if data points are to be connected by lines. = +# if data points are to be connected by lines and plotting symbols. A +4 would indicate that a special symbol is to be plotted at every fourth point. = -# if only the symbol is to be plotted (no line would be drawn).
6 8 cc `/_/_/_/`	ILNTEQ	The integer equivalent for a symbol to be used when ILINET is not 0. If ILINET is 0, then ILNTEQ should be 0. Appendix 3 contains the symbols allowed by VERSAPLOT and the corresponding code number.
9 cc `/_/`	IPENBE	The pen size (1-5) used in drawing the line connecting the points. See figure 3 for examples of different pen sizes.
10 14 cc `/_/_/_/_/_/`	IEQLL	The lower limit of the x variable in the equation. This must be an integer greater than 0. In the running skyline analysis, this is the first point for which line tensions are calculated. It should be 100 feet greater than the x coordinate of the headspar. In the surveying program, this will always be 1.

15 19 cc /_/_/_/_/_/	IEQUL	The upper limit of the x variable in the equation. This must be an integer greater than or equal to IEQLL. In the running skyline analysis, this is the last point for which line tensions are caluclated. It should be 100 feet less than the x coordinate of the tailhold. In the surveying program, this is the number of sides in the traverse.
20 24 cc /_/_/_/_/_/	IEQIN	The integer amount x is to be increased at each repetition. In general: IEQIN = (IEQUL-IEQLL)/(n-1) where n is equal to the number of points to be plotted (per equation). n can not exceed 50 unless the DIMENSION statements are changed. If the equation is a straight line, then only a few points would need to be plotted and n could have a value of 3 or 4. When the the value of IEQIN is calculated by the above expression, the value obtained must be rounded up to the next largest integer. Fractional increases in x can be obtained by the method illustrated in appendix 7. In the surveying program, this will always be 1.
25 29 cc /_/_/_/_/_/	INEGX	The integer amount subtracted from x variable at each repetition and is normally 00. It is used when negative values of x are to be graphed.
30 38 cc /_/_/_/_/_/_/_/_/./_/	STLX	This is normally 0.0. In the surveying option, it is the number of units per foot. For example, STLX: = 16.5 if the survey is in poles = 1.0 if the survey is in feet.
39 47 cc /_/_/_/_/_/_/_/_/./_/	STLY	This is normally 0.0. In the surveying option it is a code for the direction of the survey and for balancing interior angles. In this case STLY: = 0.0 for a clockwise survey with interior angles balanced before plotting. = 1.0 for a counter clockwise survey with interior angles balanced before plotting. = -1.0 if interior angles are not to be balanced before plotting

49 67 cc /_/____/_/_/	EQNAME(IP,IP1)	The description or equation form which will be printed to the right of the last (x,y) coordinates computed. This should normally be left blank when using the running skyline and surveying options.

16b(1). Card type 16b(1): (required only for running skyline)

1 cc /_/	ILIFT	= 0 if logs are lifted completely = 1 if logs are dragged
2 8 cc /_/_/_/_/_/./_/	HSBXC	The horizontal distance, in feet, the headspar is from the graph origin. The headspar must be located (graphically) to the left of the tailhold.
9 15 cc /_/_/_/_/_/./_/	HSBEL	The elevation, in feet, at the base of the headspar.
16 19 21 cc /_/_/_/./_/_/	HSHTFT	The height, in feet, of the headspar.
22 28 cc /_/_/_/_/_/./_/	THBXC	The horizontal distance, in feet, the tailhold is from the graph origin. The tailhold must be located (graphically) to the right of the headspar.
29 35 cc /_/_/_/_/_/./_/	THBEL	The elevation, in feet, at the base of the tailhold.
36 39 41 cc /_/_/_/./_/_/	THFTFT	The height, in feet, of the tailhold.
42 47 cc /_/_/_/_/_/./	WTLOAD	The weight, in pounds, of the logs.
48 53 cc /_/_/_/_/_/./	WTCAR	The weight, in pounds, of the carriage.
54 60 cc /_/_/_/_/_/_/./	WORKTN	The safe working tension of the haulback line.

16b(2). Card type 16b(2): (required only for running skyline)

1 3 5 cc /_/_/./_/_/	WTHBLF	The weight, in pounds per linear foot of the haulback line.
6 8 10 cc /_/_/./_/_/	WTMSLF	The weight, in pounds per linear foot of the main plus slack lines.

11 14 16 cc `/_/_/_/./_/_/`	DRAGA	The angle, in degrees, the logs make with the ground during yarding.
17 20 22 cc `/_/_/_/./_/_/`	FRICTC	The coefficient of friction between the log and ground (i.e. 0.60).
23 25 27 cc `/_/_/./_/_/`	CHOKER	= (log length/distance from front of log to point of choker attachment).

16c(1). Card type 16c(1): (required for surveying option, one card needed for each side of the traverse).

1 cc `/_/`	IQD	= 1 for due North and Northeast bearings. = 2 for Northwest (or due North) bearings. = 3 for due South and Southwest bearings. = 4 for Southeast (or due South) bearings.
3 4 cc `/_/_/`	IBD	The compass bearing in degress (as measured from North or South).
6 7 cc `/_/_/`	IBM	The compass bearing in minutes.
9 14 16 cc `/_/_/_/_/_/./_/_/`	DST	Length of traverse side.

INSERTING EQUATIONS OR READ STATEMENTS

In addition to completing the data card types, the user must make changes in the main program if equations or READ (and FORMAT) statements are used. The equations can be any executable FORTRAN expression, but they must be expressed in the general form of:

```
Y(INREP)=function[ X(INREP) ]
```

The function can be any mathematical equation or relationship that can be expressed by FORTRAN statements. These user supplied equations (a maximum of 10) must be inserted in specific places in the program (not with the data cards). At the specific locations within the program (table 4), the

Table 4. Program TSO line locations for inserting equations or READ and FORMAT statements.

User Written Equation or READ Statement Number*	Specific TSO Line Number	TSO Line Number Range
1	76900	75800-77400
2	78600	77500-78900
3	80200	79200-80700
4	81900	80800-82600
5	83800	82700-84200
6	85400	84300-85800
7	87000	85900-87400
8	88600	87500-89000
9	90200	89100-90600
10	91800	90700-92200

* Equation number refers to the user supplied value for IEQN in card type 16A in the documentation.

existing FORTRAN expression Y(INREP)=YOUFIX will have to be changed to the user supplied equations. Normally, only the Y(INREP)=YOUFIX in the main program will require changing. For example, if the equation y=10+5x is to be graphed, then the following FORTRAN statement would have to be written and inserted by the user at line number 76900 in the source deck (assumes that IEQN in card type 16a is 01). This would replace the current expression of Y(INREP)=YOUFIX.

```
7 cc                                       @ line number
Y(INREP)=10.0+5.0*X(INREP)                   76900
```

In some cases, a line is needed to connect data points for which there is no equation. In this case, READ and FORMAT statements can be used. The general form is:

```
     READ(KR,nnnn)X(INREP),Y(INREP)
nnnn FORMAT(F type format)
```

For example, if the data points are available and in the form of (xx.x,yyy.yy), then the following FORTRAN statements would have to be user written and inserted in the main program beginning at line number 76900 (assumes that IEQN in card type 16a is 01).

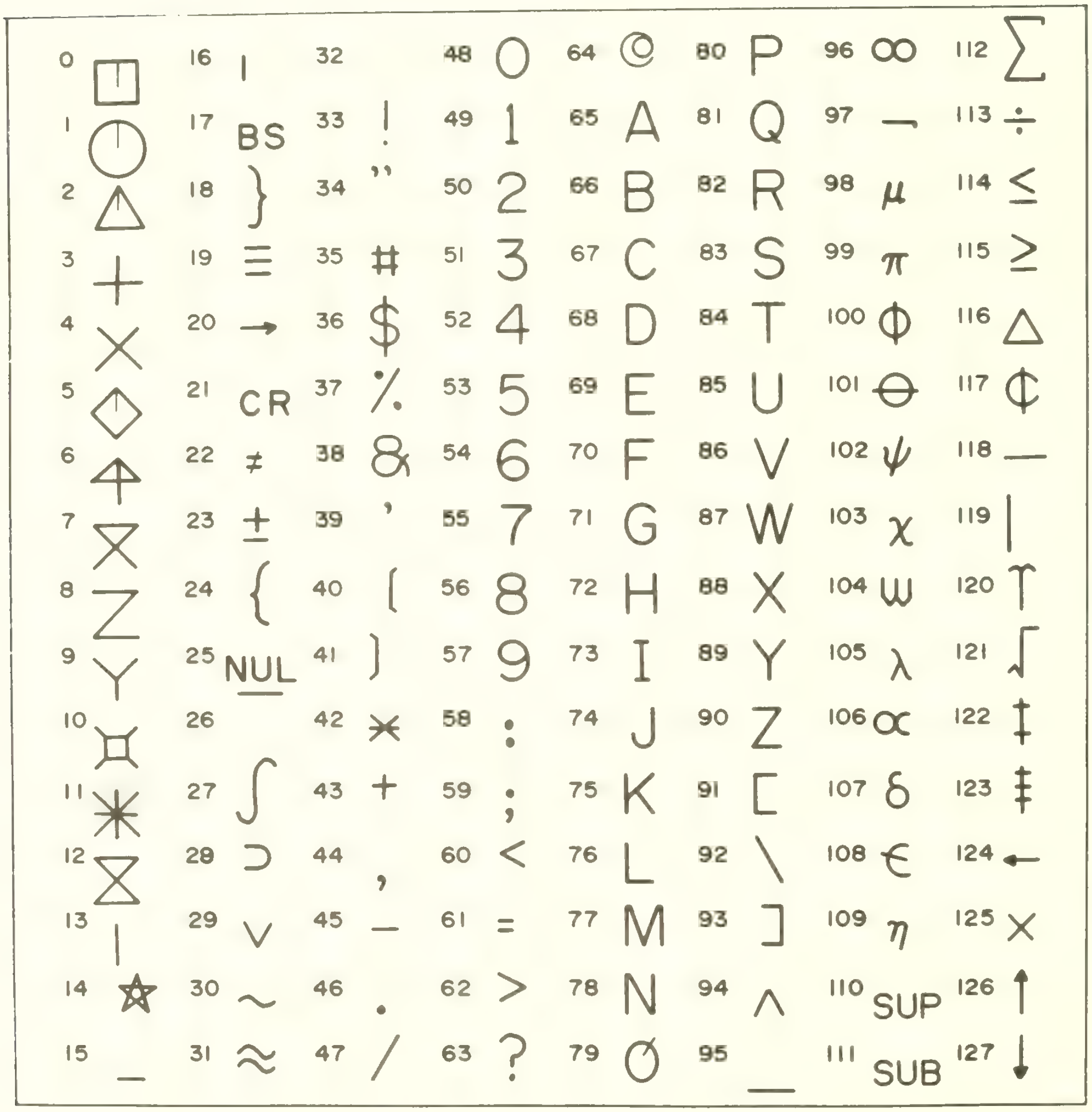
```
     7 cc                                                @ line number
     READ(KR,2370)X(INREP),Y(INREP)                        76900
2370 FORMAT(F4.1,F6.2)                                     76905
```

If several lines are to be drawn using READ and FORMAT statements, and the (x,y) input values for the different lines all have the same FORMAT (i.e. 2F4.1), then the value of IEQN in card type 16a can be the same.

The card or TSO line numbers shown in Table 4 correspond to the locations where the equations (or READ and FORMAT) statements must be user written and inserted in the program. These TSO line numbers are based on the use of 6 JCL cards and a program line numbering sequence of 100 (i.e. RENUM 100 100).

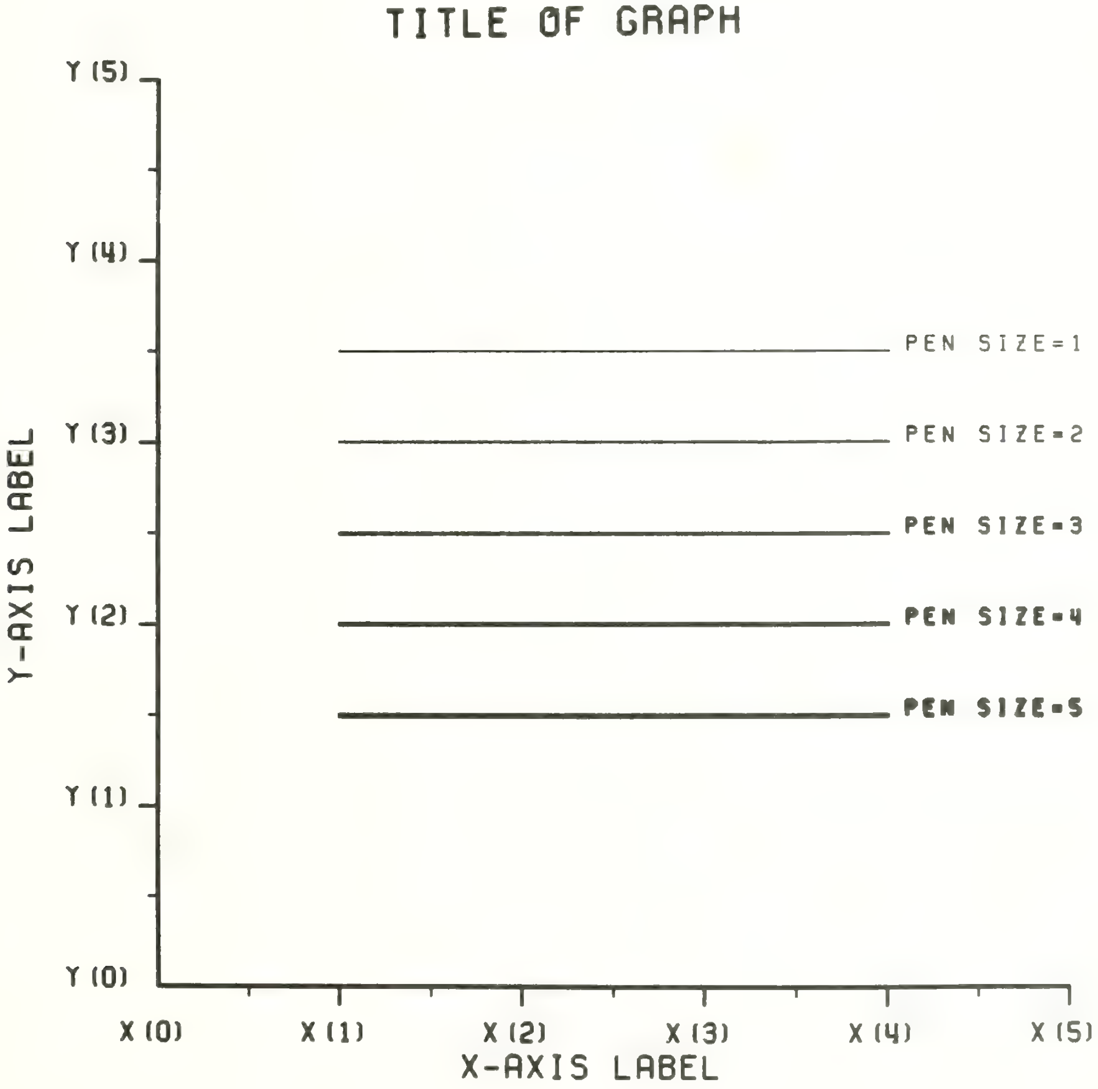
Appendix 3—Plotting Symbols and Code Numbers

Figure 2.


0
1
2
3 +
4 X
5
6
7
8 Z
9 Y
10
11
12
13
14
15 _
16 |
17 BS
18 }
19 ≡
20 →
21 CR
22 ≠
23 ±
24 {
25 NUL
26
27 ∫
28 ⊃
29 ∨
30 ~
31 ≈
32
33 !
34 "
35 #
36 $
37 %
38 &
39 '
40 (
41)
42 *
43 +
44 ,
45 -
46 .
47 /
48 0
49 1
50 2
51 3
52 4
53 5
54 6
55 7
56 8
57 9
58 :
59 ;
60 <
61 =
62 >
63 ?
64 @
65 A
66 B
67 C
68 D
69 E
70 F
71 G
72 H
73 I
74 J
75 K
76 L
77 M
78 N
79 O
80 P
81 Q
82 R
83 S
84 T
85 U
86 V
87 W
88 X
89 Y
90 Z
91 [
92 \
93]
94 ^
95 _
96 ∞
97 ⌐
98 μ
99 π
100 Φ
101 θ
102 ψ
103 χ
104 ω
105 λ
106 ∝
107 δ
108 ∈
109 η
110 SUP
111 SUB
112 Σ
113 ÷
114 ≤
115 ≥
116 Δ
117 ¢
118 —
119 |
120
121
122
123
124 ←
125 ×
126 ↑
127 ↓

Appendix 4—Standard Graph. (User supplied equations and data required to produce figure 3.)

Figure 3.--X and y axis lengths for the "standard graph" and available pen sizes



```
                 Y(INREP)=3.5


                 Y(INREP)=3.0


                 Y(INREP)=2.5


                 Y(INREP)=2.0


                 Y(INREP)=1.5
```

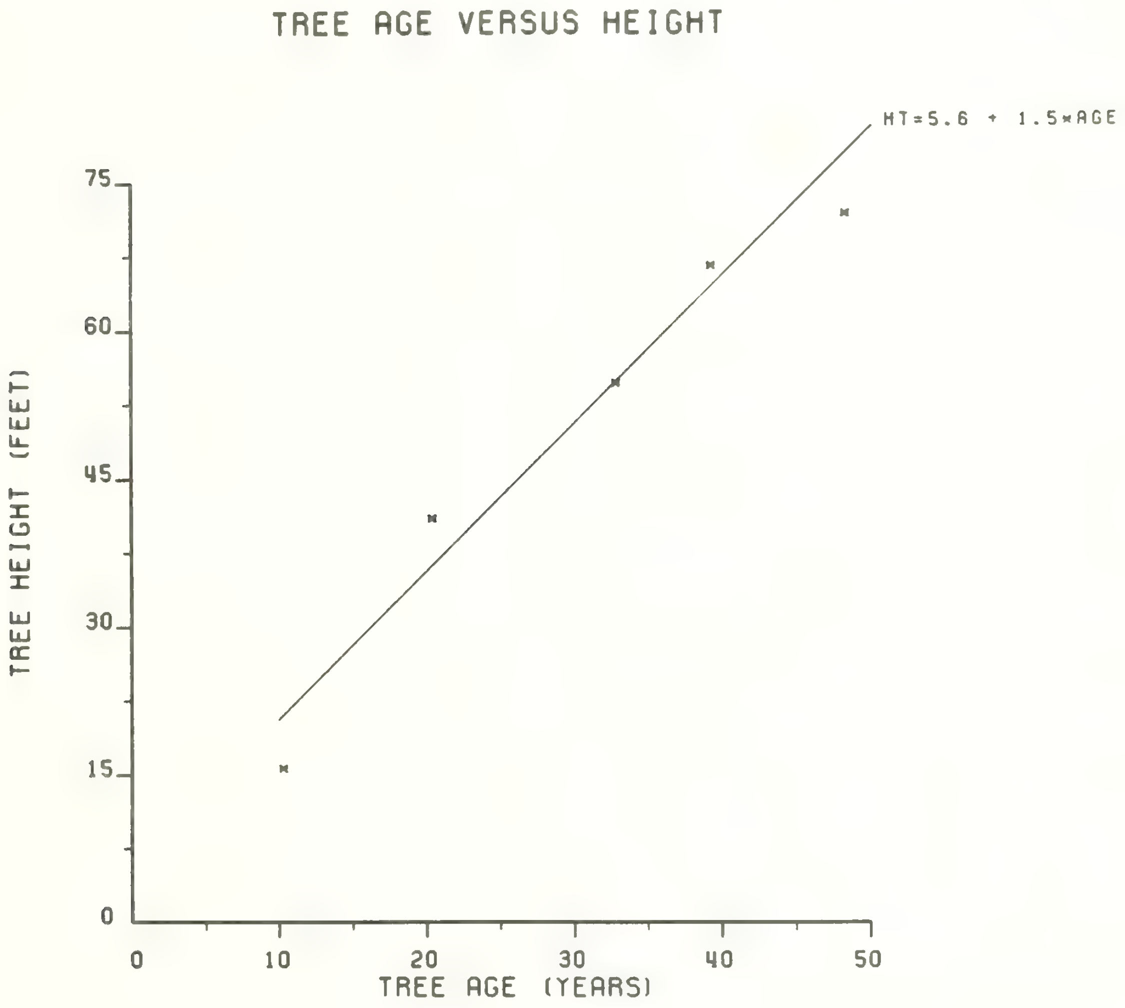
Program Listing 1.--FORTRAN statements used in figure 3. (Equations inserted at TSO line numbers 76900, 78600, 80200, 81900, and 83800, respectively.

```
//GO.SYSIN DD *
         TITLE OF GRAPH
              X-AXIS LABEL
              Y-AXIS LABEL
0
0
006100606     1.0       1.0       0.0       0.0
   X(0)
   X(1)
   X(2)
   X(3)
   X(4)
   X(5)
  Y(0)
  Y(1)
  Y(2)
  Y(3)
  Y(4)
  Y(5)
000
0000.00
00
05
01  0  01    1    4    1    0      0.0      0.0 PEN SIZE=1
02  0  02    1    4    1    0      0.0      0.0 PEN SIZE=2
03  0  03    1    4    1    0      0.0      0.0 PEN SIZE=3
04  0  04    1    4    1    0      0.0      0.0 PEN SIZE=4
05  0  05    1    4    1    0      0.0      0.0 PEN SIZE=5
//
```

Data Set 1.--Data cards used in figure 3

Appendix 5—Regression Line with Data Points Plotted. (User supplied equations and data required to produce figure 4)

Figure 4.--Regression line with data points plotted



```
Y(INREP)=5.61+1.5*X(INREP)
```

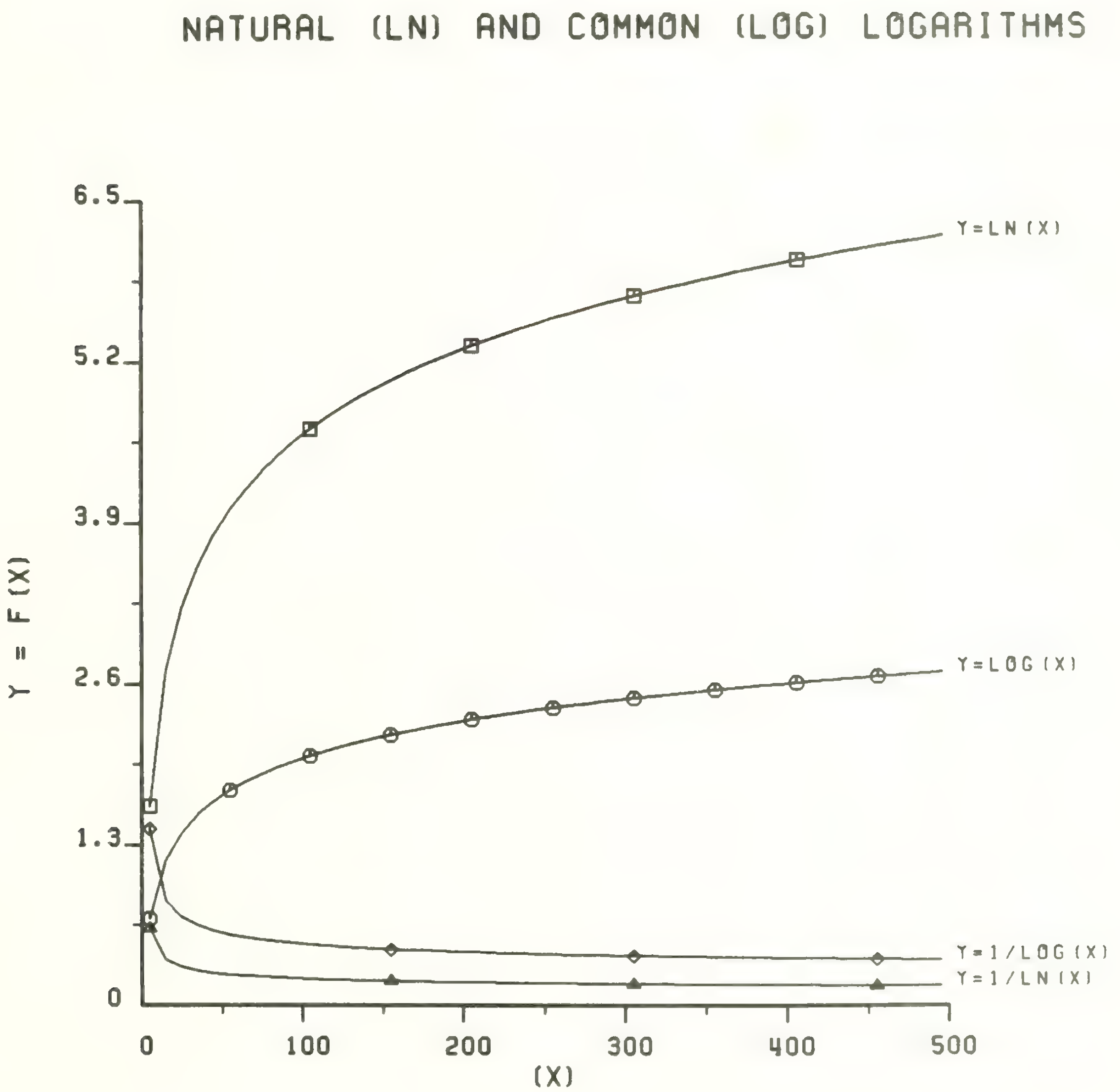
Program Listing 2.--FORTRAN statements used in figure 4. (Equation inserted at TSO line number 76900)

```
    //GO.SYSIN DD *
           TREE AGE VERSUS HEIGHT
                  TREE AGE (YEARS)
                  TREE HEIGHT (FEET)
0
0
    006100606    10.0      15.0       0.0       0.0
         0
        10
        20
        30
        40
        50
         0
        15
        30
        45
        60
        75
    101
    05*
        10.1      15.2
        20.2      40.5
        32.6      54.1
        39.0      66.0
        48.0      71.2
    0000.00
    00
    01
    01   0  02   10   50   5    0      0.0      0.0 HT=5.6 + 1.5*AGE
    //
```

Data Set 2.--Data cards used in figure 4

Appendix 6—Multiple Equations and Line Symbols. (User supplied equations and data required to produce figure 5)

Figure 5.--Multiple equations with line symbols



```
Y(INREP)=ALOG(X(INREP))


Y(INREP)=ALOG10(X(INREP))


Y(INREP)=1.0/ALOG(X(INREP))


Y(INREP)=1.0/ALOG10(X(INREP))
```

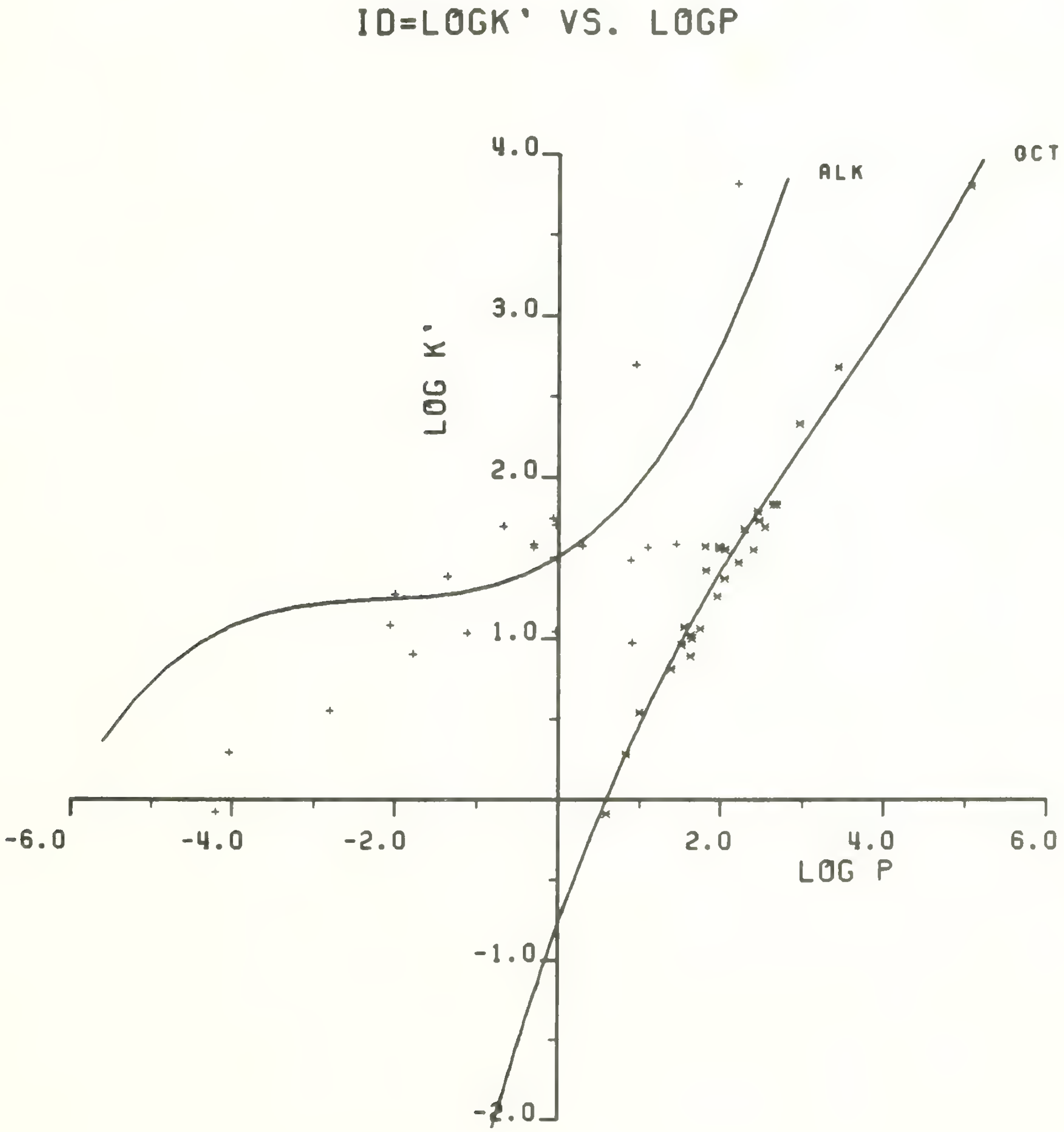
Program Listing 3.--FORTRAN statements used in figure 5 (Equations inserted at TSO line numbers 76900, 78600, 80200 and 81900, respectively)

```
//GO.SYSIN DD *
  NATURAL (LN) AND COMMON (LOG) LOGARITHMS
                  (X)
              Y = F(X)
0
0
006100606   100.0       1.3       0.0      0.0
     0
    100
    200
    300
    400
    500
     0
   1.3
   2.6
   3.9
   5.2
   6.5
000
0000.00
00
04
01 10  02    5  500   10    0      0.0      0.0 Y=LN(X)
02 05  12    5  500   10    0      0.0      0.0 Y=LOG(X)
03 15  22    5  500   10    0      0.0      0.0 Y=1/LN(X)
04 15  52    5  500   10    0      0.0      0.0 Y=1/LOG(X)
//
```

Data Set 3.--Data cards used in figure 5

Appendix 7—Non-Standard Graph. (User supplied equations and data required to produce figure 6)

Figure 6.--Changes in axis length and origin



```
      X(INREP)=X(INREP)/10.0
      Y(INREP)=1.503518+0.310558*X(INREP)+(0.132005*
     1X(INREP)*X(INREP))+(0.020165*X(INREP)*X(INREP)*
     2X(INREP))
      X(INREP)=X(INREP)/10.0
      Y(INREP)=-0.770990+1.423042*X(INREP)-(0.203330*
     1X(INREP)*X(INREP))+(0.020165*X(INREP)*X(INREP)*
     2X(INREP))
```

Program Listing 4.--FORTRAN statements used in Figure 6. Y(INREP) equations inserted at TSO line numbers 76900 and 78600 respectively Note the use of X(INREP)=X(INREP)/10.0 to obtain fractional units of X.

```
//GO.SYSIN DD *
ID=LOGK' VS. LOGP
LOC P
                   LOG K'
1
1
 -1.25  4.75  1.5  -0.5  -0.7    0.0
0
1
  4.2    3.0
0
1
432006060106.0006.0
1
-3.00-0.30-2.00-0.70-3.00-2.00
0
107100706     2.0       1.0         0.0        0.0
 -6.0
  -4.0
  -2.0

   2.0
   4.0
   6.0
  -2.0
  -1.0

   1.0
   2.0
   3.0
   4.0
102
21+
     0.86      0.93
     1.05      1.52
    -0.08      1.80
     0.84      1.44
    -0.08      1.66
    -0.11      1.70
```

```
              0.90       2.65
              2.15       3.77
              0.25       1.53
             -0.35       1.52
             -0.35       1.54
             -0.16       0.99
             -0.72       1.65
             -2.10       1.04
             -1.82       0.86
              1.40       1.54
             -1.40       1.34
             -2.04       1.23
             -2.84       0.51
             -4.08       0.25
             -4.25      -0.12
         29*
              1.47       0.93
              2.35       1.52
              2.63       1.80
              2.59       1.80
              2.17       1.44
              2.49       1.66
              2.42       1.70
              3.38       2.65
              5.01       3.77
              1.95       1.53
              2.00       1.52
              1.93       1.54
              1.58       0.99
              1.34       0.78
              1.70       1.03
              1.60       0.97
              2.24       1.65
              1.50       1.04
              1.58       0.86
              2.40       1.76
              1.93       1.53
              1.77       1.39
              2.91       2.30
              1.76       1.54



                                                   0.0       0.0   ALK
                                                   0.0       0.0   OCT
      //


      Data S
      X(INREP)=X(INREP)/10.0
      Y(INREP)=1.503518+0.310558*X(INREP)+(0.132005*
     1X(INREP)*X(INREP))+(0.020165*X(INREP)*X(INREP)*
     2X(INREP))
      X(INREP)=X(INREP)/10.0
      Y(INREP)=-0.770990+1.423042*X(INREP)-(0.203330*
     1X(INREP)*X(INREP))+(0.020165*X(INREP)*X(INREP)*
     2X(INREP))
```

Program Listing 4.--FORTRAN statements used in Figure 6. Y(INREP) equations inserted at TSO line numbers 76900 and 78600 respectively Note the use of X(INREP)=X(INREP)/10.0 to obtain fractional units of X.

```
//GO.SYSIN DD *
ID=LOGK' VS. LOGP
LOC P
                   LOG K'
1
1
 -1.25  4.75  1.5  -0.5  -0.7    0.0
0
1
  4.2    3.0
0
1
432006060106.0006.0
1
-3.00-0.30-2.00-0.70-3.00-2.00
0
107100706     2.0       1.0        0.0        0.0
 -6.0
  -4.0
  -2.0

   2.0
   4.0
   6.0
  -2.0
  -1.0

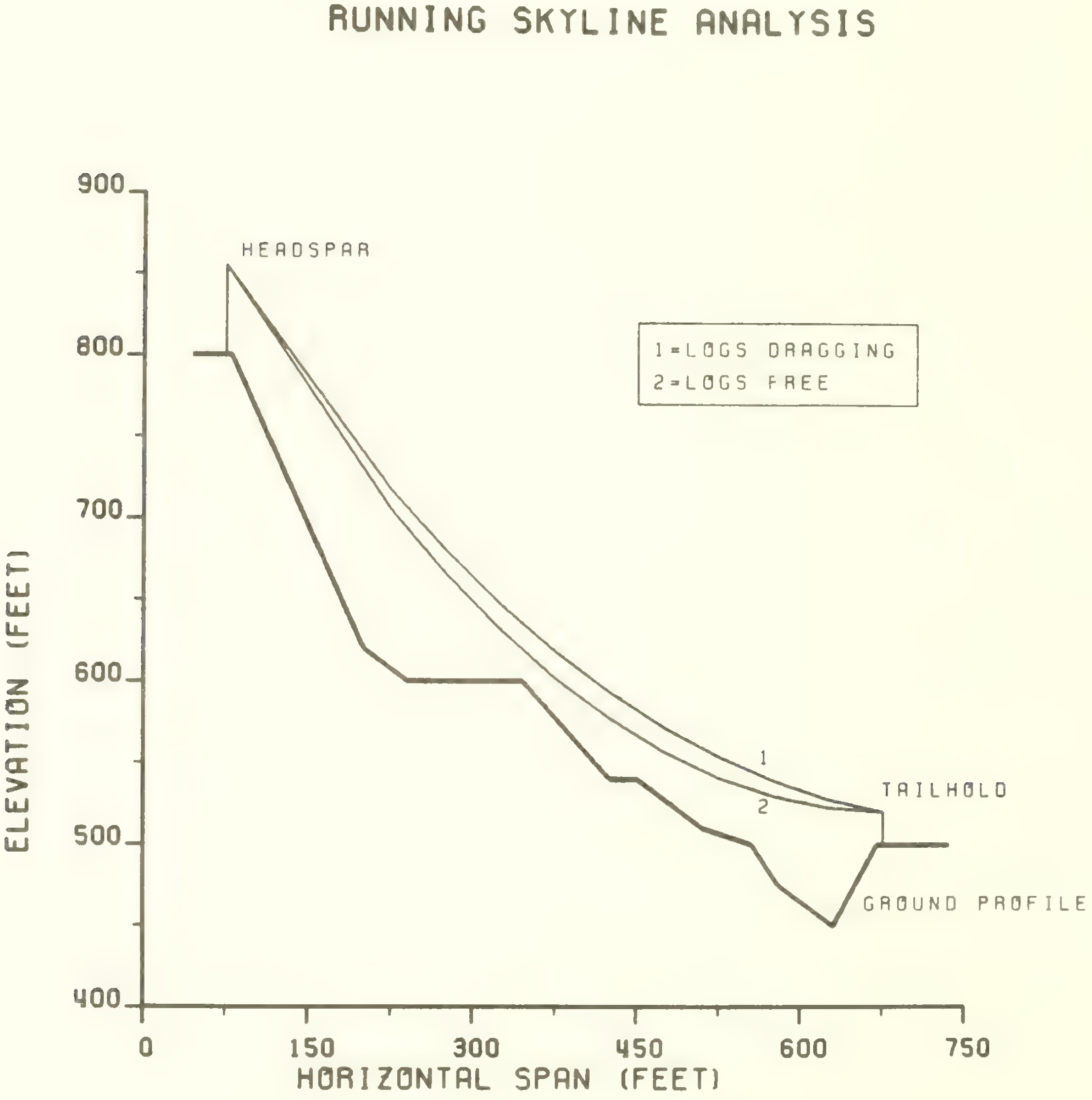
   1.0
   2.0
   3.0
   4.0
102
21+
     0.86      0.93
     1.05      1.52
    -0.08      1.80
     0.84      1.44
    -0.08      1.66
    -0.11      1.70
```

```
          0.90      2.65
          2.15      3.77
          0.25      1.53
         -0.35      1.52
         -0.35      1.54
         -0.16      0.99
         -0.72      1.65
         -2.10      1.04
         -1.82      0.86
          1.40      1.54
         -1.40      1.34
         -2.04      1.23
         -2.84      0.51
         -4.08      0.25
         -4.25     -0.12
     29*
          1.47      0.93
          2.35      1.52
          2.63      1.80
          2.59      1.80
          2.17      1.44
          2.49      1.66
          2.42      1.70
          3.38      2.65
          5.01      3.77
          1.95      1.53
          2.00      1.52
          1.93      1.54
          1.58      0.99
          1.34      0.78
          1.70      1.03
          1.60      0.97
          2.24      1.65
          1.50      1.04
          1.58      0.86
          2.40      1.76
          1.93      1.53
          1.77      1.39
          2.91      2.30
          1.76      1.54
          2.00      1.34
          1.91      1.23
          0.95      0.51
          0.79      0.25
          0.55     -0.12
     0000.00
     00
     02
     01  0  03    2   86    4   58      0.0      0.0  ALK
     02  0  03    2   62    4   10      0.0      0.0  OCT
//
```

Data Set 4.--Data cards used in figure 6

Appendix 8—Running Skyline Analysis. (User supplied READ (and FORMAT) statement and data required to produce figure 7)

Figure 7.--Projected cable pathway (log lifted and log dragging options) and ground profil



```
HEADSPAR BASE ELEV. =     800.00        LOGS DRAGGING? YES=1:  1.00
HEADSPAR HEIGHT     =      55.00        LOG LOAD WEIGHT     =  9500.00
TAILHOLD BASE ELEV. =     500.00        CARRIAGE WEIGHT     =  650.00
TAILHOLD HEIGHT     =      20.00        HAULBACK LINE LB/FT =  0.72
HORIZONTAL SEPARATION     600.00        MAIN + SLACK  LB/FT =  1.44
VERTICAL SEPARATION =     335.00        WORKING TENSION     =  10000.00
```

```
      READ(KR,1380)X(INREP),Y(INREP)
 1380 FORMAT(F5.1,1X,F5.1)
```

Program Listing 5.--FORTRAN statements used in figure 7 (READ statement inserted at TSO line number 76900)

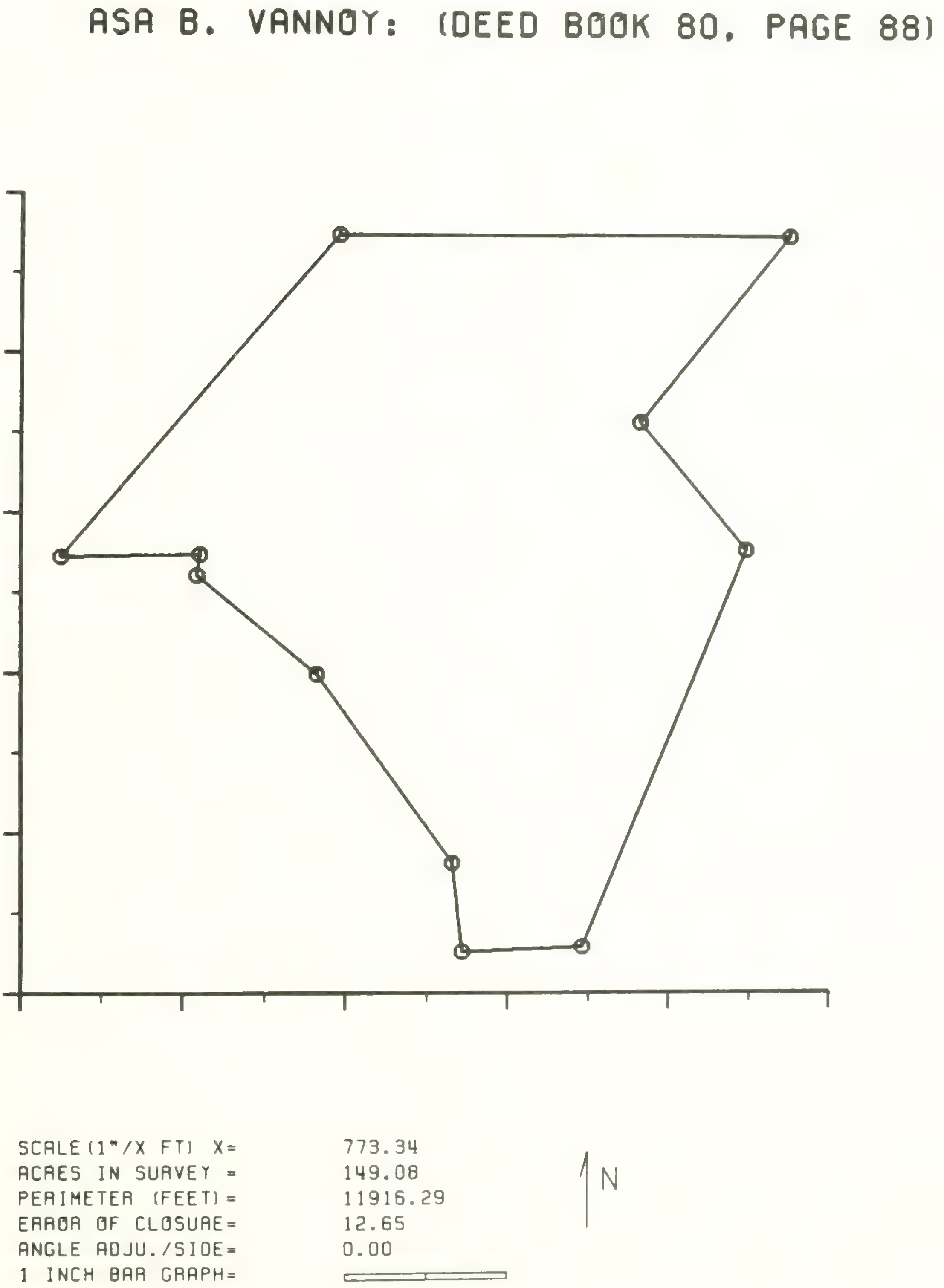
```
//GO.SYSIN DD *
        RUNNING SKYLINE ANALYSIS
        HORIZONTAL SPAN (FEET)
        ELEVATION (FEET)
0
0
106100606   150.0     100.0      0.0     400.0
     0
    150
    300
    450
    600
    750
   400
   500
   600
   700
   800
   900
000
0700.08
  0.600   4.600HEADSPAR
  4.500   1.300TAILHOLD
  4.400   0.600GROUND PROFILE
  3.750   1.5001
  3.750   1.2002
  3.000   4.000 1=LOGS DRAGGING
  3.000   3.800 2=LOGS FREE
01
05
     3.000        4.200
     4.700        4.200
     4.700        3.700
     3.000        3.700
     3.000        4.200
03
01  0  05    1   13    1    0     0.0     0.0
11  0  02  150  550   50    0     0.0     0.0
11  0  02  150  550   50    0     0.0     0.0
 45.0 800.0
 80.0 800.0
200.0 620.0
```

```
        240.0 600.0
        345.0 600.0
        425.0 540.0
        450.0 540.0
        510.0 510.0
        555.0 500.0
        580.0 475.0
        630.0 450.0
        670.0 500.0
        735.0 500.0
        1   75.0  800.0 55.0   675.0  500.0 20.00 9500.  650. 10000.
         0.72 1.44 10.00  0.60 4.00
        0   75.0  800.0 55.0   675.0  500.0 20.00 9500.  650. 10000.
         0.72 1.44  0.00  0.00 4.00
//
```

Data Set 5.--Data cards used in figure 7

Appendix 9—Survey Traverse. (User supplied data cards required to produce figure 8. Note: no equations or READ statements had to be inserted)

Figure 8.--Plot of closed boundary traverse and and pertinent survey information



```
ASA B. VANNOY: (DEED BOOK 80, PAGE 88)
```

```
SCALE(1"/X FT) X=        773.34
ACRES IN SURVEY =        149.08
PERIMETER (FEET)=        11916.29
ERROR OF CLOSURE=        12.65
ANGLE ADJU./SIDE=        0.00
1 INCH BAR GRAPH=
//GO.SYSIN DD *
     ASA B. VANNOY: (DEED BOOK 80, PAGE 88)


0
0
100000000    0.0      0.0      0.0        0.000
000
0000.00
00
01
12   1  13    1   11    1    0    16.5    1.0
3 90  00   121.0
3 37  00   118.0
1 89  00    43.5
3 03  45     6.0
4 53  15    48.0
4 39  00    71.0
4 10  30    26.5
1 88  00    38.0
1 26  15   130.2
2 36  00    46.0
1 42  00    74.0
//
```

Data Set 6.--Data cards used in figure 8

Appendix 10—CALCOMP

P-C-G can be used to produce CALCOMP graphs (ink) in addition to the standard VERSAPLOT graph (electrostatic). The following changes are required in the deck setup and source statements of P-C-G to produce CALCOMP graphs.

Deck setup

Since job control language (JCL) cards are machine dependent, the user should check the JCL documentation at each installation. The JCL needed at Auburn University (IBM 3031) for the VERSAPLOT AND CALCOMP printers are shown below.

VERSAPLOT

```
// job card
/*ROUTE PRINT LOCAL
/*JOBPARM T=30,L=30K
//STEP EXEC FORTVCLG
//FORT.SYSIN DD *
    P-C-G source deck
//GO.SYSIN DD *
    data cards
//
```

CALCOMP

```
// job card
/*ROUTE PRINT LOCAL
/*JOBPARM T=30,L=30K
//STEP1 EXEC PLOTCLG
//FORT.SYSIN DD *
    P-C-G source deck
/*
//GO.PLOT01 DD DSNAME=XYZ45.MYPLOT
//GO.SYSIN DD *
/*
//
```

Source statements:

SUBROUTINES GRID and NEWPEN are not permitted when running CALCOMP jobs at Auburn University. If these subroutines are not permitted at the user's installation, then a C should be typed (keypunched) in card column 1 of the following source statements. The associated TSO line numbers are shown for user reference and reflect the use of six JCL cards and RENUM 100 100.

TSO #	VERSAPLOT (existing)
030900	CALL NEWPEN(IPENT)
031100	CALL NEWPEN(IPENXA)

```
031300       CALL NEWPEN(IPENYA)
031800       CALL NEWPEN(IXYTA)
032800       CALL NEWPEN(IBIGT)
033700       CALL NEWPEN(ILILT)
035000       CALL NEWPEN(IXYAT)
035700       CALL NEWPEN(IBIGT)
037000       CALL NEWPEN(ILILT)
038300       CALL NEWPEN(IPENS)
044600       IF(IGRID.GT.0)CALL GRID(XSLINE,YSLINE,NX,XD,NY,YD,IGRIDN)
053000       CALL NEWPEN(1)
110600       CALL NEWPEN(1)
153700       CALL NEWPEN(1)
165000       CALL NEWPEN(JPENBE)
```

If the following TSO command is used, then a C will be placed in card column 1 of all the CALL NEWPEN lines automatically. The TSO command at Auburn University is:

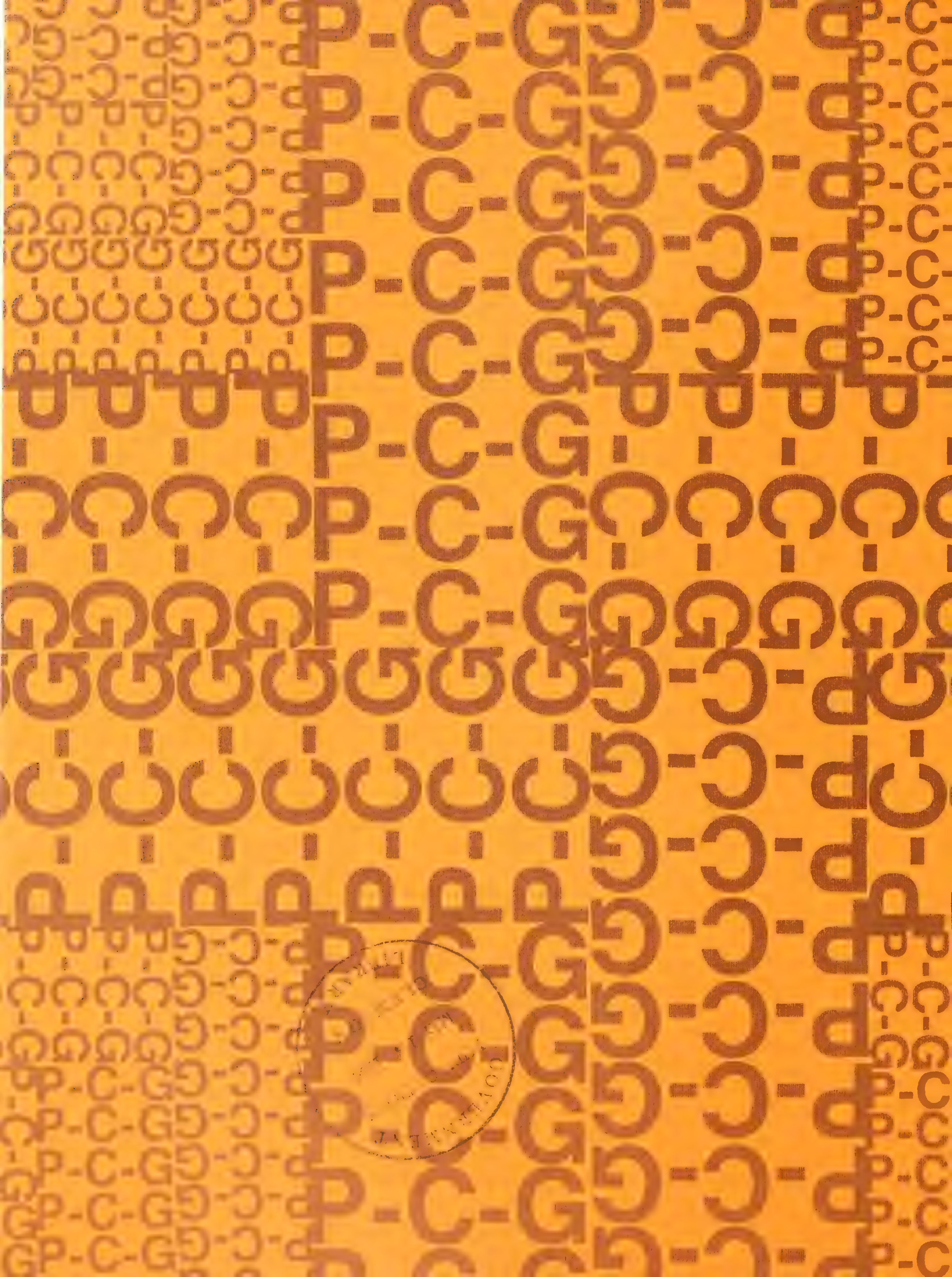
```
CHANGE 100 167500 /      CALL NEWPEN(/C     CALL NEWPEN(/ALL
```

Koger, Jerry L.; Stokes, Bryce; and Sirois, Donald L. 1983. P-C-G: Producing computer graphs. U.S. Dep. Agric. For. Serv. Res. Pap. SO-200, 40 p. South. For. Exp. Stn., New Orleans, La.

A computer program was developed to aid in the graphing of equations, data points, running skyline problems, surveying traverses, or user supplied programs. A standard procedure is provided for adding specialized user written programs. Several examples are provided to illustrate the capabilities and input requirements of P-C-G.

Additional keywords: computer programs, graphs, equations, skylining, surveying.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1984-769-089:10


P-C-G

United States
Department of
Agriculture

Forest Service

**Southern Forest
Experiment Station**

New Orleans,
Louisiana

Research Paper
SO-201
December, 1983

Wood Shipments to Puerto Rico

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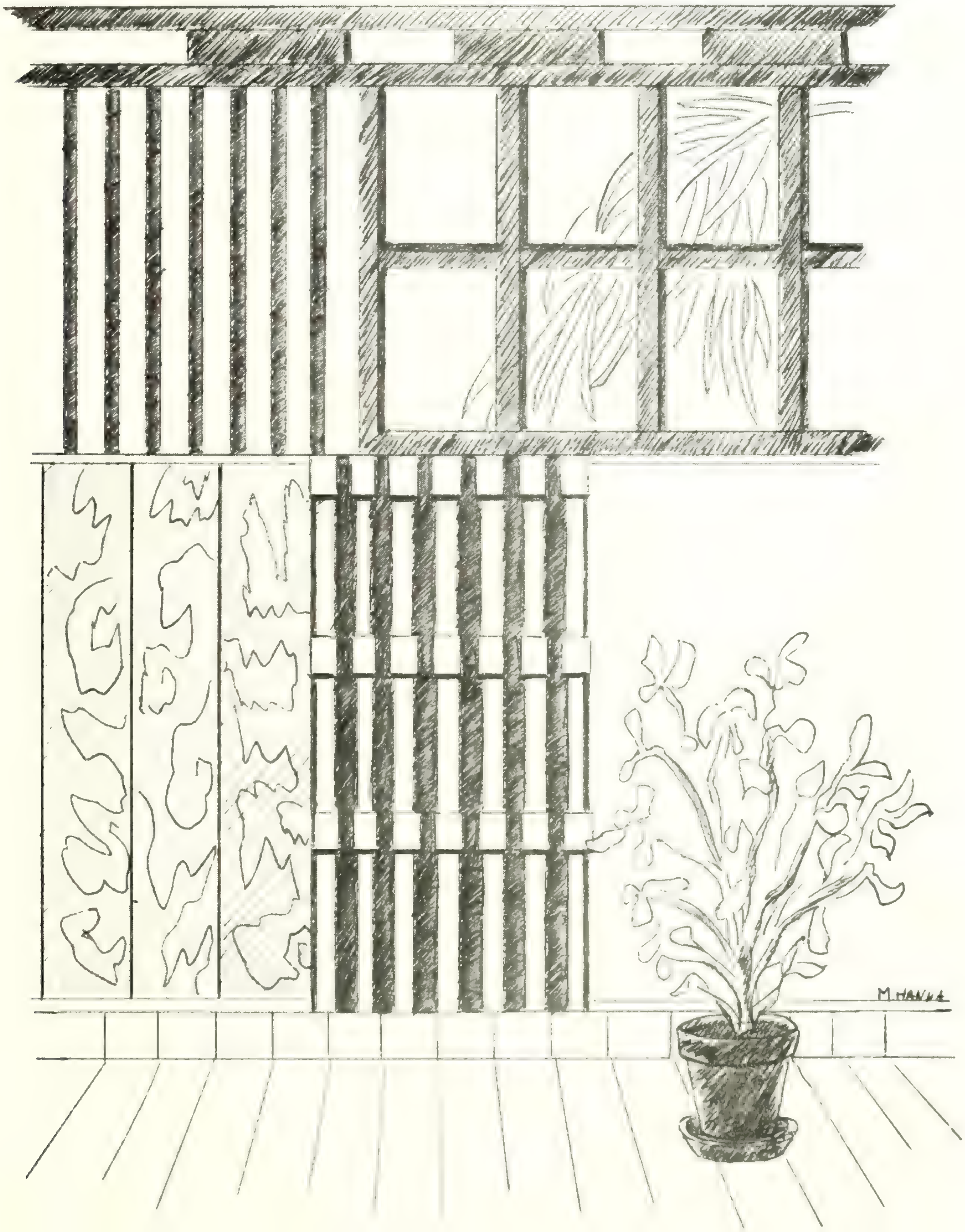
Harold W. Wisdom, James E. Granskog and Keith A. Blatner



SUMMARY

Puerto Rico's importance as an offshore market for U.S. wood products is often overlooked. Because of Puerto Rico's unique Commonwealth status, trade flows between the United States and Puerto Rico are recorded separately and are not counted in the U.S. foreign trade statistics. In 1981, wood product shipments from the United States to Puerto Rico totaled more than $61 million. Softwood plywood and lumber, primarily southern pine, accounted for more than one-half of the total value.

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Wood Shipments To Puerto Rico

Harold W. Wisdom, James E. Granskog and Keith A. Blatner

INTRODUCTION

The Commonwealth of Puerto Rico enjoys a unique political relationship with the United States. As a "freely associated state," it has unrestricted access to the U.S. market. Goods flow freely between the island and the mainland, although certain goods entering Puerto Rico may be subject to Puerto Rico's excise taxes (e.g., automobiles).

The special political arrangement between Puerto Rico and the United States creates confusion in reporting trade between the two political units. U.S. export statistics include exports from Puerto Rico to foreign countries. That is, Puerto Rico is treated merely as one more U.S. customs district, and exports from Puerto Rico are counted as part of total U.S. exports. Trade flows between the United States and Puerto Rico, recorded separately, are not counted in the U.S. foreign trade statistics, since Puerto Rico is not a foreign country.

However, the reality that Puerto Rico is an island, dependent on ocean shipping for much of its needs, distinguishes its market from that of the continental states. Rather than as a region within the U.S. economy, Puerto Rico is perhaps more associated with exporting by mainland wood shippers. But because shipments to Puerto Rico are not listed among export statistics, its importance as an offshore market—particularly for the southern forest products industry—can be overlooked.

This report describes wood product shipments from the United States to Puerto Rico. Data sources were unpublished microfiche copies and computer tapes of the Bureau of Census report EA 694, "U.S. Trade with Puerto Rico and the U.S. Virgin Islands," and selected issues of the Puerto Rico Planning Board annual report, "Puerto Rico External Trade Statistics."

BACKGROUND

Although Puerto Rico originally was largely forested with tropical species containing high quality timber, its harvesting and processing of timber products in significant quantities ceased long ago. Clearing of privately owned lands for agriculture and the removal of timber from public lands early in this century left timber harvesting a marginal economic activity in Puerto Rico. By the 1940's, the natural forest area of Puerto Rico had declined to 6 percent of the land area (Birdsey and Weaver 1982).

To encourage economic development and to reduce dependence on agriculture, Puerto Rico began to promote rapid industrialization in the late 1940's. The inability of wood products manufacturing to compete with new industries caused further decline of wood processing on the island. Fuelwood was replaced first by kerosene and later by electrical energy. Mass importation of furniture, beginning in the 1950's, almost eliminated what was formerly an important industry, the manufacture of furniture from local and other tropical woods. Rural workers migrated to the towns and cities to find jobs in the rapidly expanding industrial sector and wage rates increased rapidly. The remaining furniture and millwork industry modernized its equipment, making it intolerant of domestic lumber produced on crude mills with low quality control standards. A shift to concrete housing and the trend toward modern furniture styles further limited the market for domestic production. Increasingly, imported plywood replaced solid wood in the manufacture of furniture and in concrete forming. By the end of the 1950's, except for locally-grown posts for agriculture, these factors left the island virtually dependent upon imports to meet its wood needs.

Harold W. Wisdom is Associate Professor, Keith A. Blatner is Graduate Research Assistant, Department of Forestry and Wildlife Resources, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. James E. Granskog is Principal Economist, Southern Forest Experiment Station, USDA Forest Service, New Orleans, Louisiana. This research was funded in part by cooperative agreement No. 19-351 between Virginia Polytechnic Institute and State University and the USDA Forest Service, Southern Forest Experiment Station, New Orleans, LA. The authors thank Ralph C. Schmidt, Chief, Forest Service, Department of Natural Resources, Commonwealth of Puerto Rico, for providing Puerto Rico import statistics for lumber and plywood.

WOOD USE

Puerto Rico's use of wood is tempered by culture and climate. Concrete is the preferred housing construction material. The susceptibility of traditional wood houses to termites and hurricane damage has discouraged wood construction, except in the rural interior of the island.

Softwood lumber and plywood, meanwhile, have become important in construction, but largely for scaffolding and concrete forming (fig. 1 and 2). Structural use of lumber and plywood has been limited primarily to roof framing and roof sheathing. A smaller but active market is the decorative use of lumber, such as carports, fences, and recreation areas, where southern pine and Douglas-fir often are stained to look like redwood (fig. 3).

However, tentative evidence suggests that the strong preference for concrete housing may be weakening. In very recent years, a growing use of wood in the construction of second floors on suburban homes has occurred (fig. 4). Wooden vacation homes also have increased in the interior of the island. Whether these changes represent an aberration or a beginning trend, due to the current disparity in the costs of the two types of construction, remains to be seen.

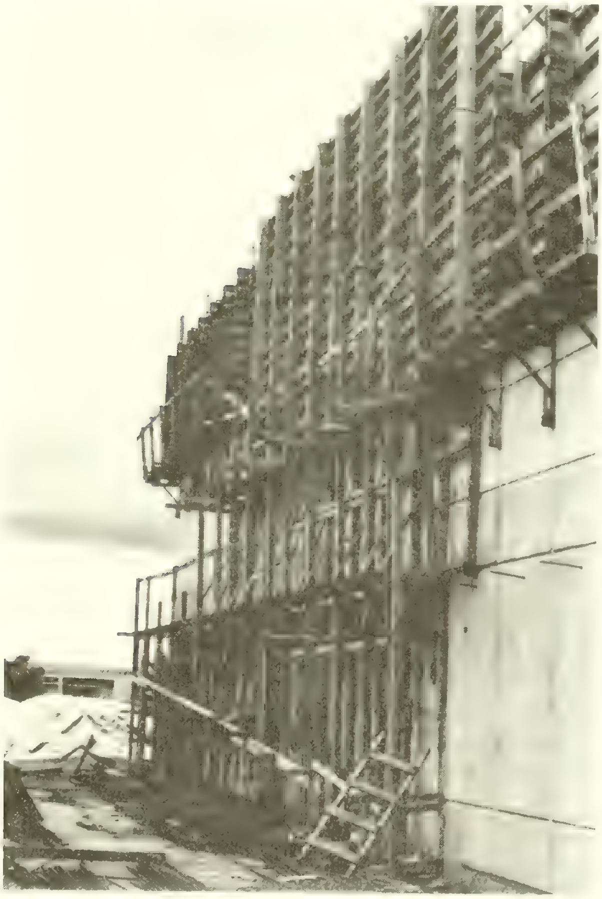

Photo by John Wisdom

Figure 1.—*The use of lumber in housing construction in Puerto Rico.*

Given its almost complete dependence upon imports, Puerto Rico today is an important market for wood products. With more than 3 million inhabitants and the highest per capita income in the Caribbean, the island has significant purchasing power. The absence of trade barriers and proximity to the United States make Puerto Rico an attractive offshore market for wood products.

U.S. SHIPMENTS

U.S. shipments of wood products—roundwood, lumber, wood-based panels, and miscellaneous manufactured products—to Puerto Rico were valued above $61 million in 1981. Shipments by major commodity group since 1971 are illustrated in figure 5. Panel products accounted for about one-half of the total value in 1981, followed by lumber with one-quarter of the value. Roundwood products, the smallest group, have exhibited the fastest growth over the decade, while miscellaneous manufactured products have experienced the slowest.

Among individual products, softwood plywood and softwood lumber have accounted for more than half of the value of shipments in recent years. The values by year for the principal products shipped, as well as volume figures cited in the following discussion of product groupings, are reported in the appendix tables.

Roundwood

Roundwood shipments in 1981 totaled $3.3 million, of which 90 percent was poles used by the government-owned electric-power utility. Shipments fluctuate according to the utility's program of line expansion and pole replacement.

Prior to 1978, shipments of poles, piling, and posts were identified separately and by different measurement units (table 1). Since 1978, these products have been regrouped according to length and treatment. Most shipments in the remaining pole and post categories are treated products.

The modest quantity of logs sent to Puerto Rico reflects the absence of a primary wood manufacturing industry. Except for a brief surge in 1975 – 78, log shipments have been less than 1 million board feet annually. Most softwood logs are southern pine; most hardwoods are oak. A substantial volume of the softwood logs may be poles and piling that have been incorrectly classified.

Lumber

Lumber shipments rose from 26 million board feet in 1971 to 55 million in 1980, before slumping to 41 million board feet in 1981. Shipments have been

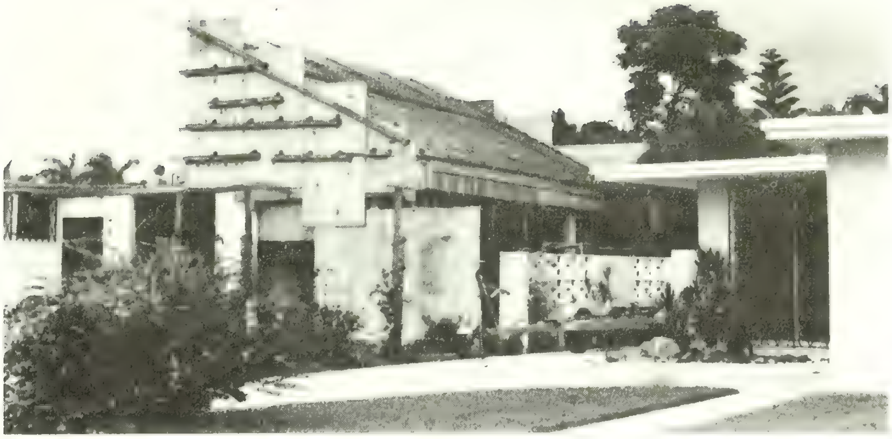

Photo by John Wisdom

Figure 2.—*The use of plywood in housing construction in Puerto Rico.*

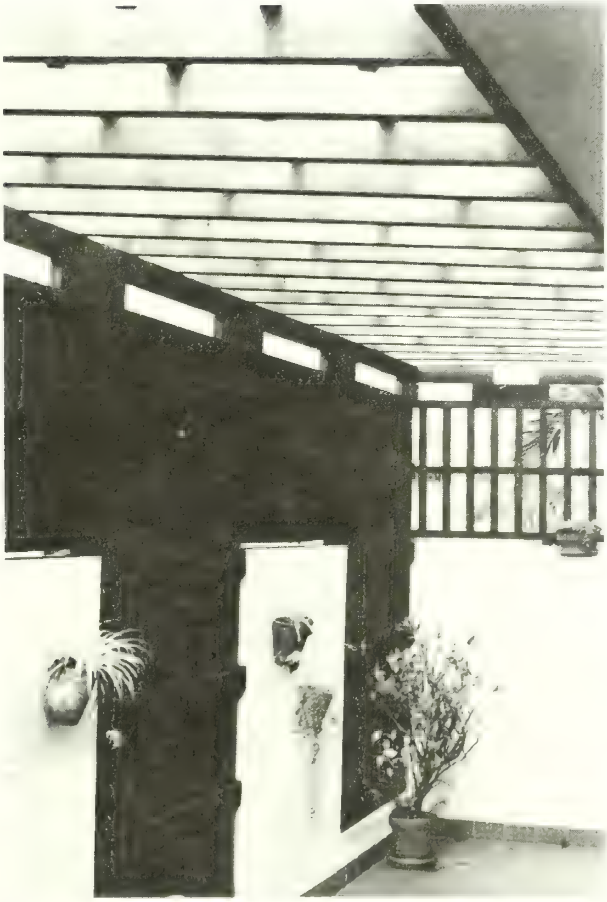

Photo by John Wisdom

Figure 3.—*The use of lumber for decorative purposes in housing in Puerto Rico (redwood and southern pine).*

Table 1.—*Roundwood shipments from the United States to Puerto Rico, 1971, 1980, and 1981*

Product	1971	1980	1981
Logs (thousand bd. ft., Scribner)	37	160	14
Piling (thousand linear ft.)	38	*	*
Poles and posts (thousands, no.)	2	27	23
Wood chips (tons)	0	213	0

*Piling is included under poles and posts.

largely softwood, although hardwood climbed to 20 percent of the total in 1981 (fig. 6).

An increasing percentage of the softwood lumber shipments has been southern pine. Since 1974, the peak year for other softwood species, southern pine jumped from 63 to 95 percent in 1981. Douglas-fir is the other principal softwood lumber species shipped. A large majority of all softwood is dressed lumber, which is typical of lumber exports to Caribbean markets.

Although hardwood lumber shipments are relatively small, they have been rising in recent years. Hardwood lumber is used almost entirely by the furniture and millwork industry. The bulkiness of assembled furniture compared with the raw material and high ocean freight rates have left furniture manufacture as one of the few wood-using industries to survive in Puerto Rico. Oak has been the most important hardwood lumber species shipped.

Wood Panels

Softwood plywood, hardwood veneer, and particleboard dominate U.S. panel shipments to Puerto Rico. Hardwood plywood shipments have been less than

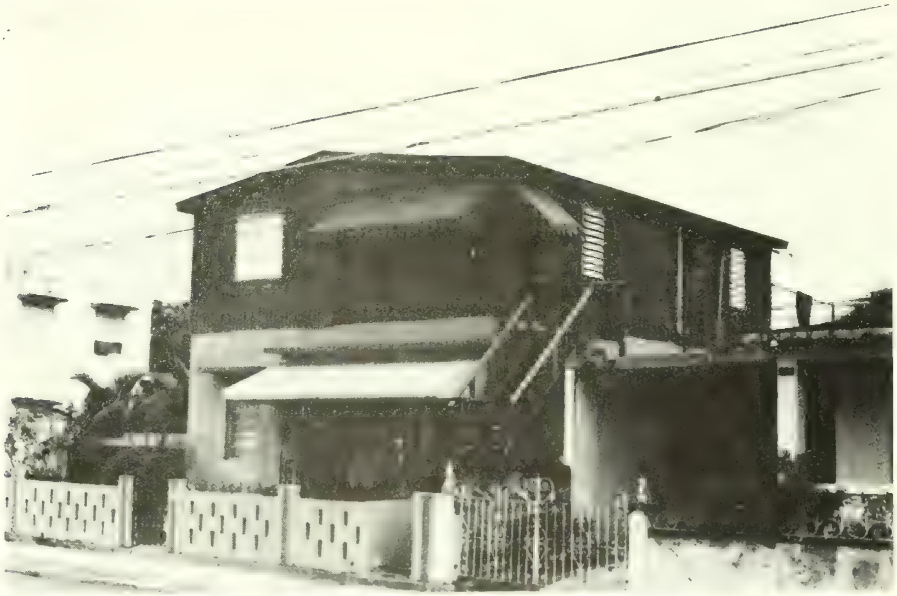

Photo by John Wisdom

Figure 4.—*The use of lumber in the second story of urban housing in Puerto Rico.*

one million square feet annually in recent years, although volume was up in 1981. Softwood veneer shipments have been minimal.

Substantial changes were made in the softwood plywood shipping classifications in 1978. Prior to 1978, softwood plywood shipments were contained in two categories—interior and exterior plywood. A third category covered shipments of plywood faced with other materials and wood veneer panels.

Since 1978, softwood plywood shipments have been classified according to species—Douglas-fir, southern pine, and other. Table 2 shows that southern pine accounts for most of the shipments. The other species category includes plywood covered with other materials, but not reinforced or backed wood veneer panels, which are now included under softwood veneer. Since most shipments are exterior grades used for concrete forming, southern pine likely constituted most softwood plywood shipped prior to 1978. Douglas-fir may represent minimal interior grade shipments.

Particleboard shipments almost equalled the value of softwood lumber shipments in 1981. Like softwood lumber, particleboard shipments are probably composed primarily of southern pine material, but source materials are not identified. Thus, Puerto Rico probably represents by far the largest offshore market for southern particleboard. Particleboard shipments to Puerto Rico averaged 34 million square feet in 1980 – 81, while annual exports of southern particleboard recently have totaled only about 11 million square feet (Wisdom, Granskog, and Peeler 1983). Particleboard is widely used for furniture manufacture and in cabinet construction.

Table 2.—*U.S. softwood plywood shipments to Puerto Rico, by species group, 1978 – 81*

Year	Total	Species Group		
		Douglas-fir	Southern pine	Other species
	thousand square feet			
1978	88,202	1,005	83,572	3,652
1979	52,039	544	49,617	1,878
1980	46,726	698	43,574	2,454
1981	72,025	721	55,271	19,033

Hardwood veneer shipments also are largely used in furniture making. Hardwood plywood shipments have been relatively small, since Puerto Rico, like the United States, imports most of its hardwood plywood from foreign sources.

Miscellaneous Manufactured Products

A wide range of miscellaneous wood articles shipped to Puerto Rico reflects the nearly total dependence of the island on outside sources for needed wood. As a group, these shipments have had the slowest growth. Although some shipments show increases in terms of current dollars, they actually have decreased when adjusted for inflation (table 3).

Among the various products, decorative wood articles—carved figures, picture frames, bookends, and jewelry boxes—are a large item. This category reflects importance, in part, of sales of wood carvings and curios to tourists. Fuelwood and charcoal shipments—mostly charcoal briquettes—also have increased significantly.

On the other hand, builders' woodwork—once the most important product category—and cooperage have declined. The growth of the millwork and joinery industry in Puerto Rico has reduced imports of doors, window units, and other millwork. Cooperage imports by the island's large rum industry have slowed in recent years.

FOREIGN SOURCES

A review of the Puerto Rico wood market requires a look at foreign sources for lumber and plywood, the two largest imports. Of particular interest to U.S. producers have been the changes among the suppliers of softwood lumber.

Lumber

Table 4 shows average annual lumber shipments to Puerto Rico from all sources for the period 1979 – 81. Receipts of hardwood lumber are small relative to softwood. The United States supplies half of the hardwood lumber, while Latin America provides the other half. Being a more heterogeneous product than softwood lumber, the desired characteristics of the various hardwood species imported—primarily oak from the United States and mahogany from Latin America—determine sources of supply more so than for softwood.

Table 3.—*Actual and deflated value of miscellaneous manufactured product shipments*

Product	Actual		Deflated*
	1971	1981	1981
	thousand dollars		
Fuelwood & charcoal	71	700	342
Cooperage	268	282	125
Builders' woodwork	1,688	780	344
Prefab. wood structures	284	322	159
Decorative wood articles	402	874	386
Wood handles	152	388	149
Other	2,295	5,808	2,843
Total	5,178	9,104	4,348

*Deflated using Producer Price Indexes for Wood Products, 1971 = 100.

Table 4.—*Average annual lumber shipments to Puerto Rico from all sources, FY 1979 – 81*

Source	Hardwood		Softwood	
	Thousand bd. ft.	%	Thousand bd. ft.	%
United States	5,854	51	39,906	39
Canada	2	*	58,399	57
Central America	270	2	2,113	2
South America	5,329	47	2,455	2
Total	11,455	100	102,873	100

*Less than 0.5 percent.

Canada currently supplies a majority of the softwood lumber. The United States and Latin America, primarily Honduras and Nicaragua, follow. In past years, however, substantial changes have occurred in the market shares held by the three major softwood lumber suppliers (table 5 and fig. 7). Southern pine from the United States dominated the softwood lumber market in Puerto Rico until the mid 1950's. But at that point, Canadian and Central American softwood imports began to increase until, by 1974, they constituted 83 percent of the market. Since 1974, the United States has recovered in part, increasing its share to about 40 percent, despite an overall decline in softwood lumber imports due to a recession in Puerto Rico's housing industry.

Decline in the U.S. share of the Puerto Rico softwood lumber market resulted from differences in ocean freight costs between foreign and U.S. shipping, a decline in the availability of southern pine lumber, and aggressive marketing by export-oriented Canadian producers. First, the Jones Act requires U.S. shippers to use relatively expensive U.S. lines, whereas Canadian and Central American shippers can use less expensive carriers. Second, following World War II, the declining southern pine lumber industry was dominated by many small operators who focused attention on domestic markets, while developing lumber industries in the competing supply areas included large-scale export operations. Thus, Puerto Rico's lumber importers could fill orders through a single supplier in Canada and Central America, whereas they often had to contact several southern suppliers. Lastly, Canadian suppliers in particular looked upon their export trade as a long-term commitment, whereas southern producers gained a reputation as "in-and-outers." That is, southern producers were perceived as interested in the Puerto Rico market only as an alternative to a depressed domestic market.

The partial recovery of market share by the United States since 1974 reflects a decline in imports from Central American and more interest by southern lumbermen in shipping to overseas markets. Lumber from Honduras has risen in cost while quality has declined as the most accessible high-quality stands have been harvested; and political unrest has disrupted the flow of lumber from Nicaragua. Since 1975, southern pine exports have risen dramatically, which demonstrates producers have increased efforts to sell lumber to all overseas markets in recent years (Granskog 1981). Canadian lumber has maintained its market share, although the volume imported has followed the overall decline in lumber imports due to the slowdown in housing construction.

Table 5.—*Softwood lumber shipments to Puerto Rico from all sources, selected fiscal years*

Fiscal year	Total, all sources	United States	Foreign sources			
			Total	Canada	Latin America	Other
	thousand bd. ft.					
1947	65,019	56,857	8,162	0	5,808	2,354
1950	76,443	65,381	11,062	5,294	5,017	751
1955	96,917	47,837	49,080	38,545	9,102	1,433
1960	117,550	27,243	90,307	68,513	20,383	1,411
1974	174,005	29,557	144,448	87,862	56,586	0
1975	120,474	32,166	88,308	65,513	22,780	15
1977	138,869	52,186	86,683	62,245	24,438	0
1978	116,094	32,830	83,264	69,851	13,413	0
1979	98,730	36,944	61,786	54,514	7,272	0
1980	126,434	48,536	77,898	72,795	5,103	0
1981	83,451	34,234	49,217	47,887	1,330	0

Table 6.—*Shipments of plywood to Puerto Rico from all sources, FY 1980*

Source	Hardwood		Softwood	
	Thousand sq. ft.	%	Thousand sq. ft.	%
United States	†	†	55,230	94
Central America	3,139	5	965	2
South America	28,721	45	508	1
Asia	32,259	50	1,932	3
Other	195	*	0	0
Total	64,314	100	58,635	100

†Although Puerto Rico government reports do not show receipts of U.S. hardwood plywood during the 1980 fiscal year, table A5 indicates average U.S. shipments for calendar years 1979 and 1980 may account for about 1 percent of Puerto Rico's hardwood plywood imports.

*Less than 0.5 percent.

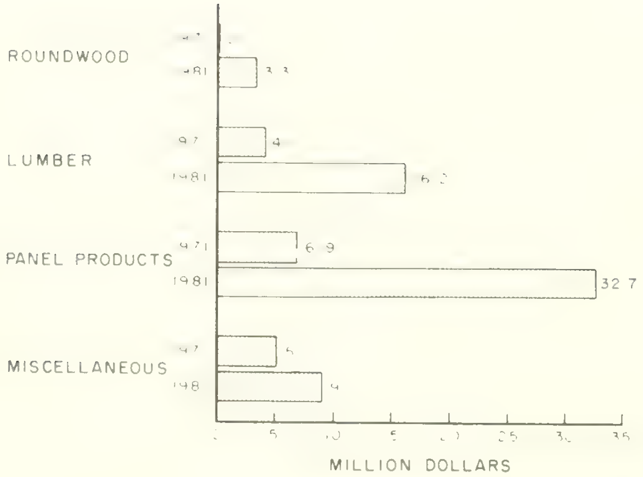

Figure 5.—*Value of wood shipments to Puerto Rico, by major products, 1971 and 1981.*

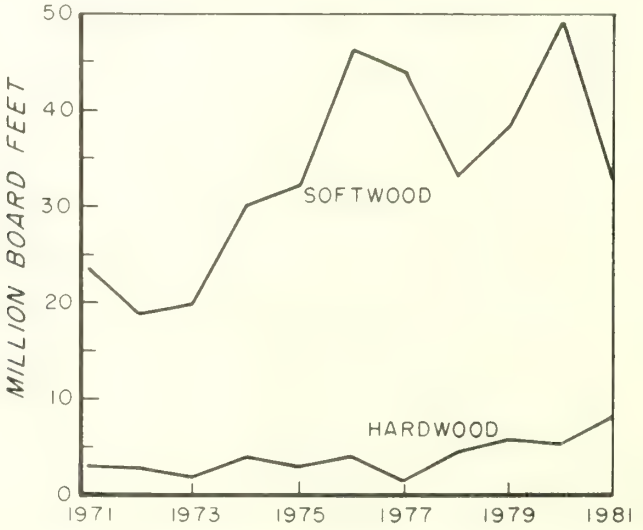

Figure 6.—*Lumber shipments from the United States to Puerto Rico.*

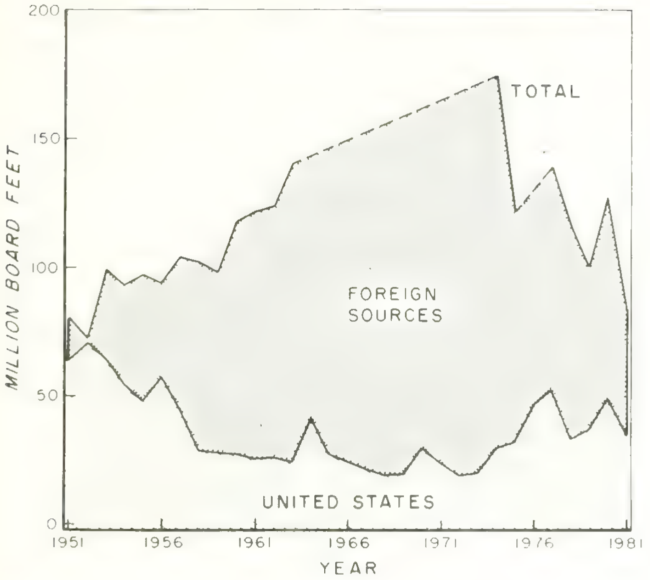

Figure 7.—*Softwood lumber shipments to Puerto Rico, from all sources, 1950 – 81.*

Plywood

Shipments of plywood to Puerto Rico from all sources for 1980 are shown in table 6. Most hardwood plywood, as noted, is imported from foreign sources—one-half from Asia and the remainder largely from South America. South Korea and Taiwan are the primary Asian suppliers, while Brazil is the principal source in South America.

Unlike the situation for softwood lumber, almost all softwood plywood is received from the United States. This predominant flow is largely explained by the competiveness of southern pine for the preferred uses and the U.S. tariff on softwood plywood imports from Canada.

DISCUSSION

The combination of a large and rapidly growing population, the highest per capita income in the Caribbean, complete dependence upon imported wood, and an absence of trade barriers make Puerto Rico an attractive market for wood products. For various reasons, however, the U.S. forest products industry has not taken full advantage of the large market at its shores. Despite the advantage of proximity and a virtual monopoly on the market until the 1950's, southern pine lumber steadily lost ground to foreign imports during the 1960's and early 1970's. Although recent events have enabled southern shippers to recapture a portion of that lost market, the statistics presented in this report suggest that southern pine shipments could be increased substantially, perhaps doubling in volume. Reaching this level will require more attention to marketing services, such as broad product mixes and security of supply.

Lumber buyers in Puerto Rico place a premium on the stability of supply. While lumber normally makes up only a small part of the total cost of housing, it still is an essential ingredient of construction methods used. Delays in construction due to the absence of forming lumber are costly far beyond the direct cost of the material. Keeping in mind that all lumber must be imported and ocean shipments may take from 3 to 4 weeks, one can readily see a secure supply is important to Puerto Rican buyers.[1]

Finally, Puerto Rico's wood imports also may be viewed as representing a potential for the resurgence of a modest wood manufacturing industry on the island, based upon the utilization of domestic woods. Following the retirement of agricultural land, the forest area has been increasing during the past 30 years. About a third of the land area is now forested, almost half of which is classed as timberland (Birdsey and Weaver 1982). However, most desirable species are in young secondary forests, and existing sawtimber of generally poor quality is scattered. Given the nature of the timber and the substantial capital investment needed for economical production of commodity-type products, substitution for softwood plywood and lumber would be difficult; yet, opportunities for small-scale production of specialty items may exist. If forest management opportunities are pursued, Puerto Rico eventually may be partially able to reduce dependence upon wood imports, and provide much needed employment in the rural areas of the island. For the foreseeable future, though, the wood market in Puerto Rico represents a sizeable opportunity for U.S. wood producers.

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[1] Personal interviews by the senior author with Mr. Raphael Del Coro and Mr. Eduardo Molino, major lumber dealers in San Juan, Puerto Rico.

APPENDIX

Statistics on Wood Product Shipments from the United States to Puerto Rico 1971 – 81

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Table A1.—*Value of wood product shipments from the United States to Puerto Rico, 1971 – 81*

Commodity	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
	thousand dollars										
Roundwood											
Softwood logs	1	24	63	101	1,186	1,050	1,062	531	277	27	2
Hardwood logs	21	43	17	158	1,150	956	755	226	143	114	11
Piling & Poles	59	348	963	2,097	5,629	1,711	4,304	917	1,317	3,041	3,022
Other Roundwood	12	15	7	20	0	26	4	175	161	496	299
Total roundwood	93	430	1,050	2,376	7,965	3,743	6,125	1,849	1,898	3,678	3,334
Lumber											
Softwood lumber	3,774	4,208	5,157	7,932	7,959	11,079	12,659	10,994	13,061	17,490	11,337
Hardwood lumber	349	428	410	999	1,011	1,155	802	1,695	2,512	2,506	4,859
Total lumber	4,123	4,636	5,567	8,931	8,970	12,234	13,461	12,689	15,573	19,996	16,196
Wood Panels											
Softwood veneer	4	0	6	0	0	0	0	6	29	25	41
Hardwood veneer	23	8	4	36	165	3	3	425	1,335	537	523
Total veneer	27	8	10	36	165	3	3	431	1,364	562	564
Softwood plywood	5,865	7,949	10,623	8,897	11,601	14,713	14,114	15,840	18,591	14,752	20,760
Hardwood plywood	566	688	1,300	3,567	939	602	551	272	319	317	833
Total plywood	6,422	8,637	11,923	12,464	12,540	15,315	14,665	16,112	18,910	15,069	21,593
Particleboard*	479	572	745	3,740	733	2,371	2,502	5,036	4,772	6,570	10,568
Total wood panels	6,928	9,217	12,678	16,240	13,438	17,689	17,170	21,579	25,046	22,201	32,725
Miscellaneous Wood Products											
Charcoal & fuelwood	71	112	197	218	363	376	331	114	458	666	700
Cooperage	286	678	730	473	494	660	476	216	779	297	282
Builder's woodwork	1,688	1,351	1,560	1,493	1,183	1,270	810	752	698	873	780
Decorative wood	402	599	775	560	448	418	862	925	1,016	923	874
Other miscellaneous	2,731	3,955	4,242	4,972	4,515	4,176	3,273	4,753	4,769	6,702	6,468
Total miscellaneous	5,178	6,695	7,504	7,716	7,003	6,900	5,752	6,760	7,720	9,461	9,104
Total Wood Products	16,322	20,978	26,799	35,263	37,376	40,566	42,508	42,877	50,237	55,336	61,359

*Includes other reconstructed wood.

Table A2.—*Roundwood shipments from the United States to Puerto Rico, 1971 – 81*

Year	Logs	Piling	Poles
	thousand bd. ft.	*thousand lin. ft.*	*No.*
1971	37	38	2,366
1972	194	1	6,466
1973	290	5	20,243
1974	623	10	30,674
1975	7,402	36	70,980
1976	6,704	138	28,404
1977	4,881	0	29,452
1978	1,192	*	10,848
1979	400	*	12,069
1980	160	*	26,909
1981	14	*	22,789

*Since 1978, piling has been included under poles.

Table A3.—*Softwood lumber shipments from the United States to Puerto Rico, 1971 – 81*

Year	All softwood			Southern pine			Other softwoods*		
	Total	Rough	Dressed	Total	Rough	Dressed	Total	Rough	Dressed
	thousand board feet								
1971	23,476	5,439	18,037	16,870	4,111	12,759	6,606	1,328	5,278
1972	18,656	4,923	13,733	13,733	2,747	10,626	5,283	2,176	3,107
1973	19,871	5,962	13,909	13,073	2,228	10,845	6,798	3,734	3,064
1974	30,083	9,610	20,473	19,061	5,539	13,522	11,022	4,071	6,951
1975	32,166	10,958	21,208	28,016	9,534	18,482	4,150	1,424	2,726
1976	46,338	8,347	37,991	43,356	7,661	35,695	2,982	686	2,296
1977	43,938	7,333	36,605	40,947	5,370	35,577	2,991	1,963	1,028
1978	33,432	4,899	28,533	30,430	4,813	25,617	3,002	86	2,916
1979	38,615	6,387	32,228	34,507	6,133	28,374	4,108	254	3,155
1980	49,330	7,121	42,209	44,923	6,568	38,355	4,407	553	3,854
1981	32,650	5,180	27,470	31,051	4,581	26,470	1,599	599	1,000

*Primarily Douglas-fir.

Table A4.—*Hardwood lumber shipments from the United States to Puerto Rico, by species, 1971 – 81*

Year	Total	Ash & Hickory	Oak	Walnut	Other
	thousand bd. ft.				
1971	2,873	96	1,395	9	1,373
1972	2,793	21	1,288	23	1,461
1973	1,907	13	896	0	998
1974	3,877	247	792	1,014	1,824
1975	2,965	358	637	0	1,970
1976	3,953	86	2,138	150	1,579
1977	1,499	38	513	58	890
1978	4,489	14	2,883	97	1,495
1979	5,884	0	4,312	0	1,572
1980	5,411	25	2,254	115	3,017
1981	8,152	18	2,181	25	5,928

Table A5.—*Wood panel shipments from the United States to Puerto Rico, 1971 – 81*

	Veneer			Plywood				Particleboard
Year	Total	Softwood	Hardwood	Total	Softwood	Hardwood	Other	
	thousand square feet							
1971	839	16	823	41,648	39,301	1,204	1,143	3,431
1972	184	0	184	46,929	43,663	1,939	1,327	5,135
1973	233	205	28	49,214	44,629	2,380	2,205	4,914
1974	1,280	0	1,280	57,452	48,048	5,408	3,996	22,194
1975	3,340	0	3,340	68,152	64,961	1,122	2,069	4,229
1976	190	0	190	71,384	62,831	709	7,844	13,694
1977	79	0	79	49,500	48,069	442	989	13,167
1978	10,766	136	10,630	89,168	88,202	880	86	4,374
1979	44,808	233	44,575	53,051	52,039	476	536	28,750
1980	19,558	396	19,162	47,866	46,726	839	301	39,538
1981	23,957	383	23,574	78,956	75,025	3,725	206	28,630

Table A6.—*Shipments of miscellaneous wood articles from the United States to Puerto Rico, 1971 – 81*

Year	Total	Fuelwood & charcoal	Cooperage	Builder's wood work	Prefab wood structures	Decorative wood articles	Wood handles	Other
	thousand dollars							
1971	5,178	71	286	1,688	284	402	152	2,295
1972	6,695	112	678	1,351	315	599	707	2,933
1973	7,504	197	730	1,560	277	775	507	3,458
1974	7,721	218	473	1,493	263	560	387	4,322
1975	7,003	363	494	1,183	311	448	238	3,966
1976	6,900	376	660	1,270	191	418	254	3,731
1977	5,752	331	476	810	293	862	278	2,703
1978	6,760	114	216	752	334	925	150	4,269
1979	7,720	458	779	698	274	1,016	94	4,401
1980	9,461	666	297	873	306	923	154	6,242
1981	9,104	700	282	780	322	874	338	5,808

Wisdom, Harold W.; Granskog, James E.; Blatner, Keith A. Wood Shipments to Puerto Rico. Res. Pap. SO-201. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1983. 11 p.

U.S. shipments of wood products—roundwood, lumber, wood-based panels, and miscellaneous manufactured products—to Puerto Rico are presented for the years 1971 through 1981.

Additional keywords: Foreign trade, forest products, overseas markets.

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Structure and Composition of Moist Coastal Forests in Dorado, Puerto Rico

Julio C. Figueroa, Luis Totti, Ariel E. Lugo, and Roy O. Woodbury

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SUMMARY

A survey of forest structure, species composition, and change in forest areas over a 44 year period was conducted on 39.5 ha of forest lands in Dorado, Puerto Rico, where H. A. Gleason and M. T. Cook had studied forest conditions in 1926. A total of 51 tree species were found in the study area. Six forest types were identified on white sands and poorly drained clay soil. The most complex forest was the 19.7 m tall old secondary forest with 32 tree species, 1,880 stems/ha, a basal area of 41.6 m^2/ha, and a complexity index of 493. Abandoned palm groves (5 tree species), a disturbed open forest with 9 tree species and dominated by *Hymenaea courbaril*, a Clusia-Zyzygium forest (11 tree species), and a young secondary forest with 19 tree species (also dominated by *H. courbaril*) were all undergoing succession towards the old secondary forest. This forest is considered to be the climax on white sands. In flooded soils, *Pterocarpus officinalis* and six other tree species form a climax swamp forest that has not changed in composition for the last 54 years. In terms of forest area, however, Pterocarpus and old secondary forests have been reduced by 30 percent and 79 percent, respectively. The primary cause of the changes in forest areas has been human intervention: direct, through cutting, and indirect, through changes in drainage conditions. The study forests, however, support four endangered plant species and an endangered bird species. Their social, scientific, and intrinsic values are significant.

Cover photo: *Isolated Pterocarpus forest trees in the Dorado golf course.*

Structure and Composition of Moist Coastal Forests in Dorado, Puerto Rico

Julio C. Figueroa, Luis Totti, Ariel E. Lugo, and Roy O. Woodbury

INTRODUCTION

In 1926, H. A. Gleason and M. T. Cook (1927) studied the moist coastal forests on property belonging to a Ms. Livingston, located just west of Dorado, Puerto Rico. They described in some detail what they termed "the forest of the lowland white sands," dominated by *Mammea americana* and *Calophyllum brasiliense.* These trees were up to 20 m in height and about a meter in diameter. Gleason and Cook reported that, due to clearing for agriculture, forests such as these had all but disappeared from the north coast of Puerto Rico. The estate of Ms. Livingston contained what they considered the only undisturbed remnant of this type. Fifty-four years later, in 1980, the U.S. Forest Service was asked by the new owners of this property to evaluate the condition of the forests in a 39.5 ha section (known as "Parcel F") that encompasses the forested areas visited by Gleason and Cook in 1926. Because of the importance of this forest type to the general understanding of forests in Puerto Rico's north coast, the U.S. Forest Service's Institute of Tropical Forestry agreed to conduct the study. An analysis that paralleled that of Gleason and Cook's was undertaken. Additional observations were made to describe, in quantitative terms, changes that have occurred since that time. This paper describes the results of the recent study and compares them with the observations made by Gleason and Cook.

SITE DESCRIPTION

The study site lies within the subtropical moist forest life zone (Ewel and Whitmore 1973), northwest of the town of Dorado on the north coast of Puerto Rico (fig. 1). Mean annual temperature is 25.4°C, and total annual rainfall is 1,688 mm (Álvarez 1982). Elevation ranges from 0 to 10 m above sea level. Deposited sands of both tuffaceous and calcareous origin (Roberts 1942), with varying drainage capacities, comprise the soils within the site (fig. 2):

- Cataño sand (well-drained phase). This soil is found in long narrow strips (some wider than 300 m) along the coastline. It is characterized by a 15 to 20 cm thick dark friable sandy surface layer underlain by a lighter colored calcareous layer. In the past, coconut plantations were grown on these soils.
- Cataño sand (poorly-drained phase). This soil is similar to the one just described, but because of its location (at low elevations close to lagoons or the ocean) the water table is within 45 cm of the surface and drainage is poor.

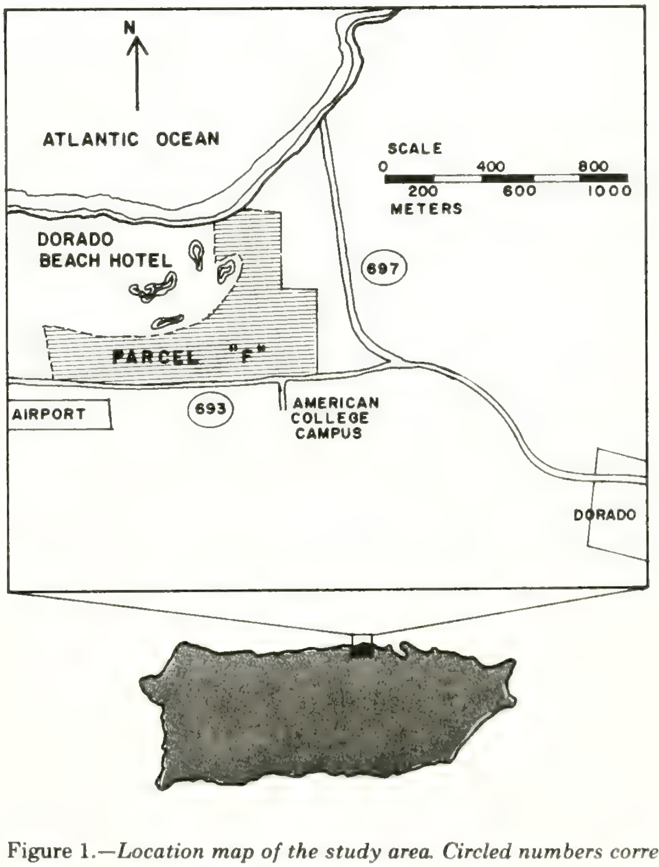

Figure 1.—*Location map of the study area. Circled numbers correspond to State Roads.*

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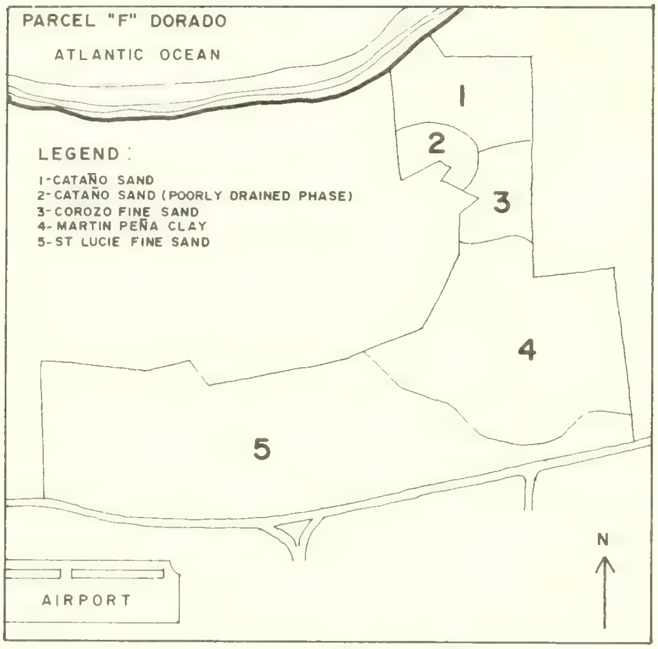


Figure 2.—*Soils map of the study area (Roberts 1942).*

- Corozo fine sand. This soil is landward from the previous two and is one of the most infertile soils of the coastal plains. It is well drained but extremely acid.
- Martin Peña clay. This soil is characterized by a dark plastic acid clay surface layer 20 to 25 cm thick overlying a layer of lighter colored, more compact plastic clay that gradually changes to substratum at a depth of 75 to 100 cm. This substratum is similar to the subsoil but less heavy and more compact. Martin Peña clays occupy low areas intermediate in location between the soils of the coastal lowlands and river flood plains. The water table is high, keeping the compact subsoil wet for considerable time periods throughout the year. As a consequence, there is practically no natural surface drainage, and internal drainage is restricted.
- St. Lucie sand. This soil is readily recognized by its nearly white surface color and dune-like relief. Its strongly acid, fine-sand surface layer changes very little in color, texture, structure, or consistency for depths of up to 4 m. In some places, though at considerable depths, this soil is underlain with material very similar to that found under Corozo fine sand. Though faintly developed in some areas, an organic hardpan layer is present throughout.

METHODS

The study consisted of three phases. First, a preliminary survey of species and tree communities wa performed throughout the property to gain familiar zation with the vegetation and the site. Next, 21 10 × 10 m plots were placed randomly throughout th property. All individuals with a diameter at breas height (dbh) greater than 2.5 cm were indentified i each plot. Measurements of dbh and height wer taken and the crown position noted. With these data stand basal area, tree density, species importanc values, and complexity index were calculated. Th complexity index was calculated as the product o basal area, stand density, tree height (average o three tallest trees), and number of species (in 0.1 ha divided by 1000 (Holdridge 1967). All species nomenclature is in accordance with that of Liogier and Martorell (1982). Aerial photographs obtained from th Puerto Rico Highway Authority were used to delineate forest types and study changes in coverage ove 44 years, using photos for 1937, 1950, and 1981.

Table 1.—*Structure of six forest types recognized on the moist coastal white sands of Dorado, Puerto Rico (Parcel "F")*

Forest type	Study plots†	Number of species	Tree density∞	Basal area	Heightξ	Complexity* index
			no/ha	*m^2/ha*	*m*	
Abandoned palm grove	2	5	1600	32.6	12.3	32
Disturbed and open	2	9	1000	21.8	17	33
Pterocarpus forest¶	...	7	1680	44.6	19.0	100
Clusia-Syzygium	6	11	3200 (567)§	25.6 (7.0)	20.7	187
Young secondary	6	19	1833 (174)	29.0 (7.1)	19.3	194
Old secondary	5	32	1880 (299)	41.6 (5.3)	19.7	493

†All plots were $100\ m^2$ and all trees with diameter at breast height > 2.5 cm were considered.
∞Clumps were counted as 1 individual.
ξAverage of tallest three trees.
*Complexity index = (no. of tree species) (tree density) (basal area) (height) (10^{-5}).
¶From Alvarez 1982.
§Standard error of mean is in parentheses.

Table 2.—*Relative values of tree density and basal area for the three most important species in each forest type of a coastal moist forest in Dorado, Puerto Rico*

Species	Tree density†	Basal area	Importance value‡
	percent		
Old secondary forest			
Manilkara bidentata	21	42	32
Lonchocarpus latifolius	6	11	9
Pisonia subcordata	8	4	6
Sub-total	35	57	47
29 other species	65	43	53
Young secondary forest			
Hymenaea courbaril	19	48	34
Bucida buceras	11	21	
Quararibaea turbinata	12	3	8
Sub-total	32	72	53
16 other species	68	28	47
Clusia-Syzygium forest			
Clusia rosea	28	81	55
Syzygium jambos	54	12	33
Ocotea leucoxylon	6	2	4
Sub-total	88	95	92
8 other species	12	5	8
Pterocarpus forest			
Pterocarpus officinalis	74	48	61
Bucida buceras	14	43	29
Calophyllum brasiliense	10	5	8
Sub-total	98	96	98
4 other species	2	4	2
Disturbed open forest			
Hymenaea courbaril	13	55	34
Syzygium jambos	42	10	26
Ocotea leucoxylon	21	4	13
Sub-total	76	69	73
6 other species	24	31	27
Abandoned palm grove			
Cocos nucifera	22	84	53
Lonchocarpus latifolius	42	10	26
Amphitecna latifolia	25	2	14
Sub-totals	89	96	93
2 other species	11	4	7

†Relative values of density and basal area expressed as percentages of the totals for each type.

‡Importance value = relative density + relative basal area divided by 2.

*From Alvarez 1982.

RESULTS

Six forest types were recognized in the study area in 1981 (table 1, fig. 3c). The groupings were selected for convenience and reflect stands that can be easily identified by their physiognomy as dictated by previous land use. However, we will refer to the traditional forest nomenclature in several locations in the text where such distinction is necessary. The structure and species composition of the six forest types mapped will be discussed according to their vegetation complexity, beginning with the simplest forest. Table 2 lists the dominant species on each forest type and their importance value.

Abandoned Palm Grove

This grove was once a commercial plantation and is now invaded by successional species such as *Lonchocarpus latifolius, Amphitecna latifolia*, and *Cordia laevigata.* Five tree species were found on the two plots established in this forest type. The grove was planted on Cataño and Corozo sands and had the shortest canopy height but a relatively large basal area. This area is notable because it supports the largest breeding colony of the endangered white-crowned pigeon (*Columba leucocephala*) on the north coast of Puerto Rico (Wiley 1979).

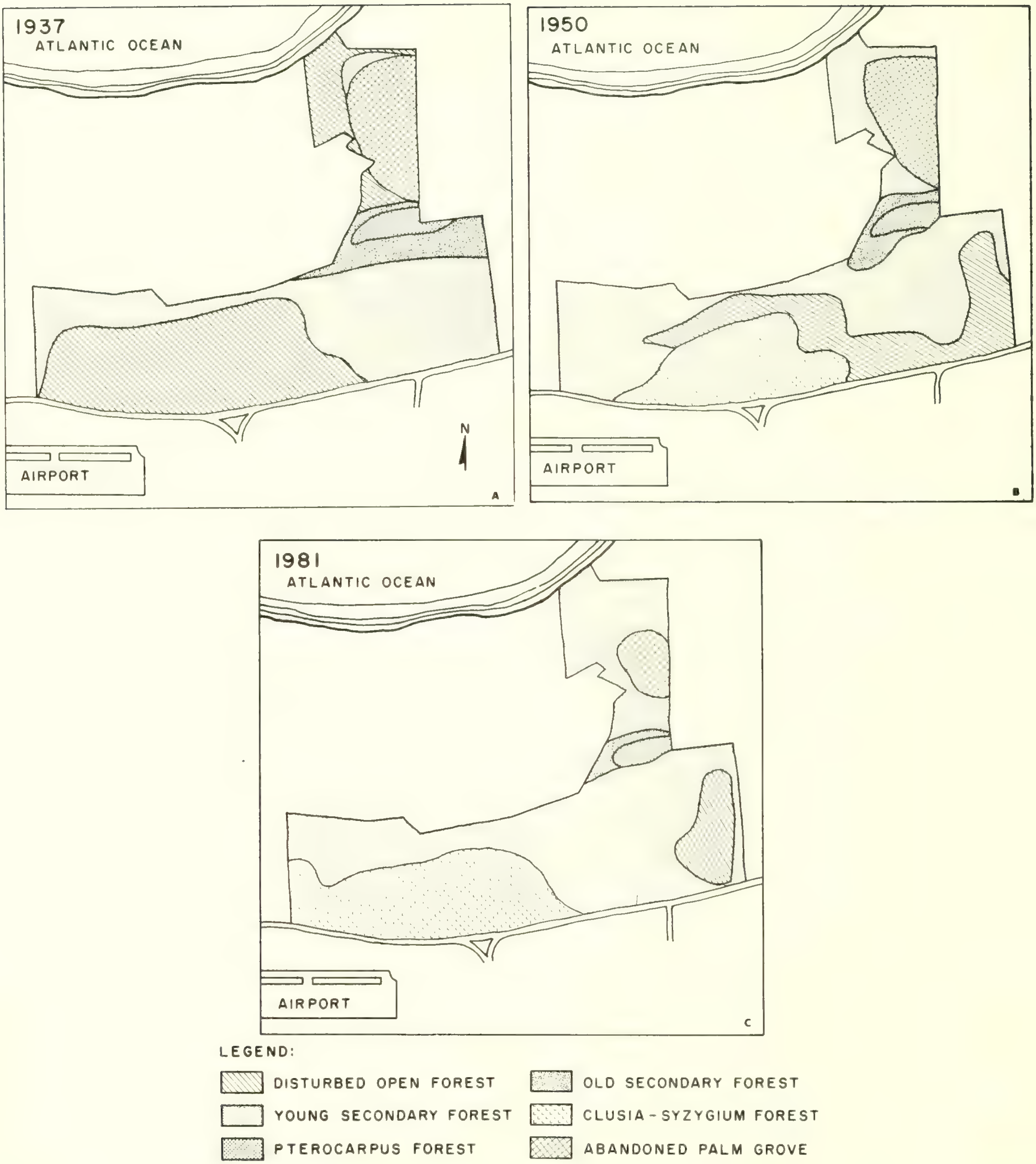


Figure 3.—*Maps of forest types in the study area corresponding to: (a) 1937, (b) 1950, and (c) 1981.*

Disturbed Open Forest

This forest is located on the southeastern portion of the property. Nine tree species were found in this forest type, dominated by *Hymenaea courbaril, Syzygium jambos,* and *Ocotea leucoxylon.* The forest tree density and basal area were 1,000 trees/ha and 21.8 m^2/ha. Canopy height was 17 m. This forest exhibited successional characteristics such as a high density of vines and wide open areas with few large trees.

Pterocarpus Forest

This forest wetland covers 0.7 ha of poorly drained Martin Peña clays. Seven tree species are found in this area, but only one species is dominant, *Pterocarpus officinalis.* Other species of importance were *Bucida buceras* and *Calophyllum brasiliense.* No experimental plots were established in this area, because this particular forest stand was studied in detail by Álvarez (1982).

Clusia-Syzygium Forest

This forest type was found as an uninterrupted block along the southern portion of the property. The forest is swampy, although it grows on Saint Lucie sands. The dominant species were *Clusia rosea, Syzygium jambos, and Ocotea leucoxylon.* The forest had a very high proportion of multiple stems, probably due to coppicing encouraged by past tree cutting.

Young Secondary Forest

Over half of Parcel F (23.9 ha) is dominated by this forest type. The dominant tree species were *Hymenaea courbaril, Bucida buceras,* and *Quararibaea turbinata.*

Old Secondary Forest

This was by far the most complex forest type sampled. It was found surrounding the Pterocarpus forest on Martin Peña clays. The forest is characterized by the presence of such species as *Manilkara bidentata, Lonchocarpus latifolius, Pisonia albida, Calophyllum brasiliense, Mastichodendron foetidissimum, Zanthoxylum martinicense,* and *Ocotea globosa.* Areas within this forest type were found completely covered by the herbaceous *Anthurium crenatum.* This is a unique forest and one of the two remaining examples of fairly undisturbed moist coastal forests in Puerto Rico. The other example is located in the Manati area, west of the study site.

Changes in Forest Area

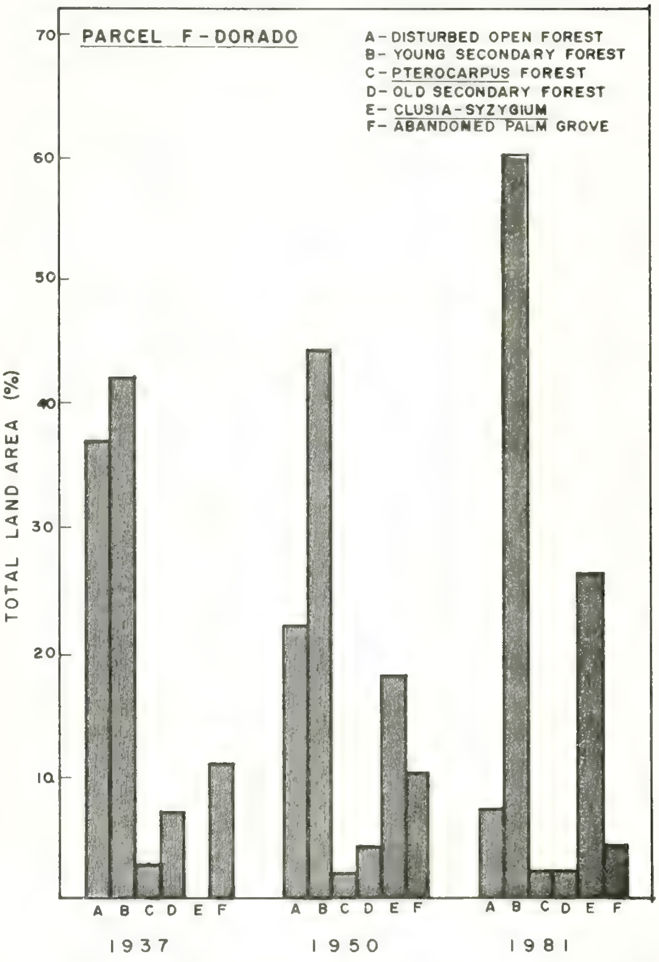
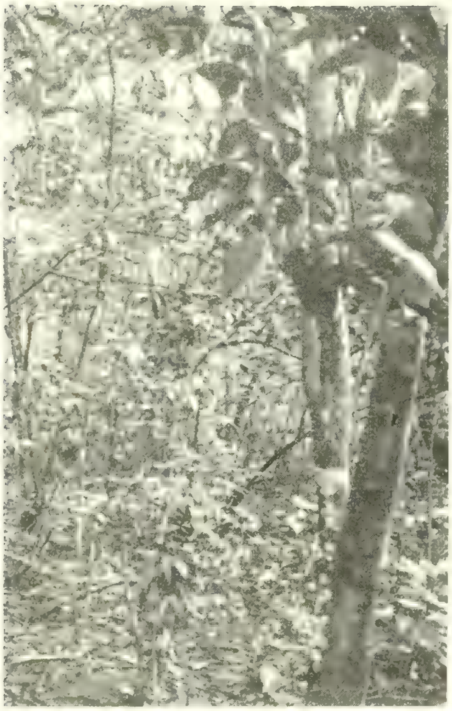


Figure 4.—*Changes in the proportion of total land area covered by each of six forest types in the study area.*

In figures 3(a–c) and 4, we reconstructed the historical change in forest cover on the study site. In 1937 (fig. 3a) 90 percent of the property was in some degree of alteration (i.e. disturbed open, young secondary forest, and coconut plantation). The Clusia-Syzygium forest could not be detected in the photograph. Only 10 percent of the area was in natural forest. By 1950 (fig. 3b), the area of old secondary forest had decreased 46 percent and the area of Pterocarpus forest had been reduced by 10 percent (table 3). A Clusia-Syzygium forest replaced most of the disturbed open forest while the palm grove was invaded by secondary forest. Today (fig. 3c), young secondary forest covers 60 percent of the site and all other forest types have decreased in proportion. Construction of a golf course west of the study area has caused changes in drainage patterns resulting in serious declines of both the Pterocarpus and old secondary forests. On the southern portion of the site, the successional Clusia-Syzygium forest has continued to increase in area, partly due to impeded drainage in the area.

In summary, net changes over the last 44 years show an 82 percent decrease in disturbed open forest (replaced by the Clusia-Syzygium forest); a 30 percent loss of Pterocarpus forest, a 79 percent loss of old secondary forest, and an encroachment of 64 percent into the palm grove by young secondary forest.



Abandoned palm grove being invaded by secondary forest.

Disturbed open forest.

Pterocarpus forest.

Clussia-Zyzygium forest.

Old secondary forest.

Young secondary forest.

Table 3.—*Temporal change in areal distribution by forest type in Parcel F, Dorado, Puerto Rico*

Forest type	Area†		
	1937	1950	1981
		ha	
Old secondary forest	2.8	1.5	0.6
Young secondary forest	16.5	17.2	23.9
Clusia-Syzygium forest	.....	7.4	10.1
Pterocarpus forest	1.0	0.9	0.7
Disturbed open forest	14.8	8.5	2.6
Abandoned palm grove	4.4	4.0	1.6

†Total area of Parcel F is 39.5 ha.

Table 4.—*Endangered plant species in the coastal moist forest of Dorado*

Forest type	Endangered species	Life form
Young secondary forest	*Cassia mirabilis* (E)†*	herb
Pterocarpus forest	*Sabicea cinerea*	shrub
Pterocarpus forest	*Epidendrum kraenzlinii* (E)	epiphyte
Old secondary forest	*Ficus stahlii**	tree

†(E) = Endemic.
*Observed on the property.

Species Relationships

Our survey of the arboreal vegetation was sufficient to typify species composition in the study site. All communities were sampled at an intensity sufficient to obtain a species-area curve with a flat asymptote (fig. 5). It is obvious from these curves that the richest forest stand was the old secondary forest followed by the young secondary forest. Table 5 contains a listing of all tree species encountered in the survey. Four presently considered endangered species were observed in the study site (table 4). It is clear from these results that the study area has a rich and unique assemblage of tree and other plant species. The old secondary forest supports 84 percent of all the species in the region. Thus, as already suggested by Gleason and Cook, the forest communities in Parcel F, with the exception of the Pterocarpus forest, are all part of one floristic assemblage that converges in a climax forest similar to the old secondary forest. This forest is known either as a moist coastal forest on white sands or as a coastal dry evergreen forest on silica sands.

DISCUSSION

Comparison With the Survey of Gleason and Cook

Not all of the species listed by Gleason and Cook in 1926 were sampled on the site in the present study. The extensive loss of mature forest area could explain why some were not encountered. The most significant changes, however, have been in the area occupied by the different forests. For example:

The original beach strand forest formation has been almost completely altered. Considerable time and lack of additional disturbance would be needed for this area to revert to its natural state. This beach strand formation that once included over 100 woody species, harboring trees over 10 m in height, was dominated by species of *Cassine, Coccoloba,* and *Morinda.* Today, young secondary forests occupy these locations.

The dry evergreen forest located next to the beach and north of the Pterocarpus swamp forest was a two-storied formation with strata at 10 and 20 m. This forest had several tree species that attained diameters of 1 m or more. Examples are *Bucida buceras, Calophyllum brasiliense, Mammea americana, Mastichodendron foetidissimum,* and *Manilkara bidentata.* Many smaller trees reached the upper canopy, such as *Lonchocarpus latifolius, Ocotea patens, O. globosa, Chione venosa, Zanthoxylum martinicense,* and *Cupania americana.*

The second story (10 m) was dominated by such trees as *Faramea occidentalis, Ixora ferrea, Eugenia biflora, Mouriri helleri, Casearia guianensis, Pimenta racemosa var. grisea,* and *Ardisia obovata.* Today, except for the area next to the Pterocarpus swamp forest, this area is mostly coconut grove and young secondary forest covered with *Cocos nucifera, Terminalia catappa,* and *Bucida buceras.*

The original coastal dry evergreen forest on silica sand was also disturbed. This forest was originally dominated by the following large upper story trees:

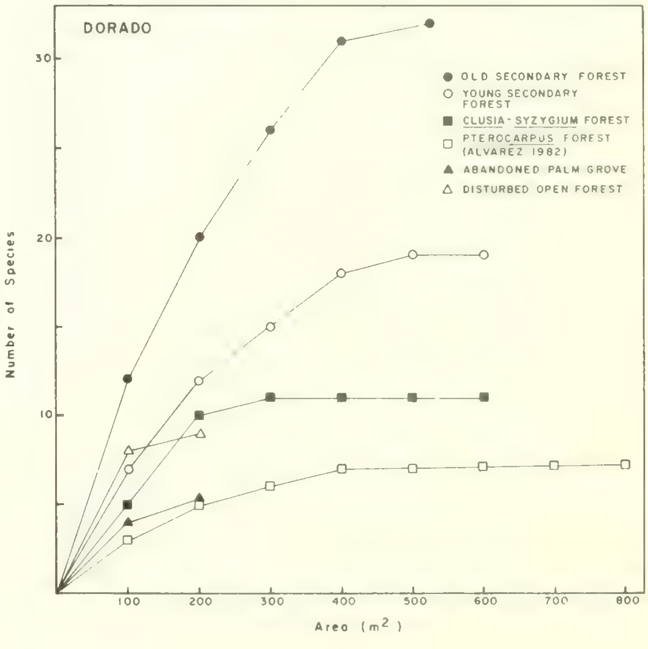


Figure 5.—*Species-area curve for six forest types in the study area.*

***Hymenaea courbaril*, *Buchenavia capitata*, *Spondias mombin*, *Andira inermis*, *Manilkara bidentata*, *Ficus trigonata*, *Guapira fragrans*, *Cinnamomum elongatum*, *Ocotea floribunda*, *O. patens*, *O. globosa*, *Inga fagifolia*, *Guarea guidonia*, and *Mastichondendron foetidissimum*.**

The disturbed areas today contain mostly *Clusia rosea* and *Syzygium jambos*. The majority of these disturbed areas are in different stages of recovery as indicated by the following trees: *Myrcia splendens*, *Eugenia biflora*, *Myrciaria floribunda*, *Ocotea patens*, *O. globosa*, *Faramea occidentalis*, *Buchenavia capitata*, *Ardisia obovata*, *Chione venosa*, *Cupania americana*, *Montezuma grandiflora*, *Spondias mombin*, *Andira inermis*, *Byrsonima spicata*, *Zanthoxylum martinicense*, and other less common species.

The swampy Pterocarpus forest was and still is dominated by *Pterocarpus officinalis*. Co-dominant

Table 5.—*Distribution of all tree species tallied by forest type in the moist coastal forests of Dorado, Puerto Rico*

Species	Forest types					
	Secondary		Clusia-Syzygium	Pterocarpus†	Disturbed open	Abandoned palm grove
	Old	Young				
Alchornea latifolia Sw.			X			
Andira inermis (W. Wright) HBK.	X	X	X	X		
Amphitecna latifolia (Miller) A. Gentry*						X
Bourreria succulenta Jacq. var. *succulenta*	X					
Buchenavia capitata (Vahl) Eichl.	X					
Bucida buceras L.		X	X	X		
Bursera simaruba (L.) Sarg.*	X	X				
Byrsonima spicata (Cav.) HBK.					X	
Calophyllum brasiliense Jacq.*	X			X		
Calyptranthes sintenisii Kiaersk.	X	X				
Casearia guianensis (Aubl.) Urban*	X	X				
Chrysophyllum argenteum Jacq.	X					
Citharexylum fruticosum L.	X					
Clusia rosea Jacq.*			X			
Coccoloba diversifolia Jacq.	X					
Cocos nucifera L.						X
Cordia laevigata Lam.	X					X
Cupania americana L.*		X				
Dendropanax arboreus (L.) Decne. & Planch*	X					
Dendropanax laurifolius (E. March.) Decne. & Planch ex. Schneid.*	X					
Didymopanax morototoni (Aubl.) Decne. & Planch	X		X		X	
Drypetes alba Poir			X			
Eugenia biflora (L.) DC.	X	X				
Eugenia monticola (Sw.) DC.*	X		X			X
Faramea occidentalis (L.) A. Rich.		X				
Ficus citrifolia P. Miller				X		
Guapira fragrans (Dum.-Cours.) Little	X	X				
Guarea glabra Vahl.		X			X	
Hymenaea courbaril L.		X	X		X	
Inga fagifolia (L.) Willd.	X	X				
Licaria parvifolia (Lam.) Kostermans		X				
Lonchocarpus latifolius (Willd.) DC.	X					X
Mangifera indica L.					X	
Manilkara bidentata (A. DC.) A. Chev.*	X	X			X	
Myrcia leptoclada DC.	X				X	
Myrcia floribunda (West ex Willd.) Berg.		X				
Ocotea coriacea (Sw.) Britton*	X					
Ocotea globosa (Aubl.) Schlecht. & Cham.	X					
Ocotea leucoxylon (Sw.) Mez.	X	X	X		X	
Ouratea littoralis Urban			X			
Palicourea crocea va. *riparia* (Benth.) Griseb.*	X					

Table 5.—*Distribution of all tree species tallied by forest type in the moist coastal forests of Dorado, Puerto Rico—Continued.*

Species	Forest types					
	Secondary		Clusia-Syzygium	Pterocarpus†	Disturbed open	Abandoned palm grove
	Old	Young				
Piper aduncum L.*	X					
Pisonia subcordata (Sw.) ex Standl.*	X					
Pterocarpus officinalis Jacq.				X		
Quararibaea turbinata (Sw.) Poir.		X				
Randia aculeata L.*				X		
Roystonea borinquena O.F. Cook*‡				X		
Syzygium jambos (L.) Alst.*			X		X	
Tabebuia heterophylla (DC.) Britton*	X					
Trichilia hirta L.	X					
Zanthoxylum martinicense (Lam.) DC.*	X	X				
Total	32	19	11	7	9	5

†From Alvarez 1982.

*Also recorded by Gleason and Cook (1926).

‡Endemic.

species include *Bucida buceras, Roystonea borinquena,* and several fringe species such as *Andira inermis, Calophyllum brasiliense, Manilkara bidentata, Ardisia obovata, Ocotea leucoxylon, Coccoloba venosa,* and *Calyptranthes sintenisii.* The main impact on this forest has been its reduction in area rather than a change in species composition.

The Factors of Change

Many factors combine to cause vegetation changes such as those described. However, two can be singled out in the study site: 1) direct human intervention by cutting and replanting, and 2) indirect human effects mostly through changes in drainage. Direct human intervention was responsible for the destruction of the beach strand vegetation (through planting of the coconut grove) and most of the changes that occurred on the southern portion of the property near the road. These forces are no longer active, and the vegetation on these areas is in a clear process of recovery. But the speed of recovery is slow because the infertile soils present regeneration problems to the forest communities.

Changes in drainage are more subtle in their effect, but they nevertheless have played a significant role in reducing the area of both Pterocarpus and old secondary forests. The last extension to the golf course was particularly harmful in this respect (see cover).

In addition to these two major forces of change, it is evident that the area has been subjected to selective logging in the past. This has left its mark on the forest in a profusion of vines and an abundant number of sprouts and coppice growth in the surviving stumps.

Forest Values

It is obvious that the old secondary forest and the Pterocarpus forest cannot sustain much more human impact and still survive. These forest types are among the most endangered forest ecosystems in Puerto Rico. Their value rests in their limited representation elsewhere, high biological productivity, unique habitats, and outstanding floral composition. Because they grow in stressed environments (one is a wetland and the other grows on very nutrient-poor sands), they are also of unique interest to science and acquire enormous intrinsic and social value.

The young secondary forests and the Clusia-Syzygium forest represent two advanced stages of forest recovery in the region. Their species-area curves (fig. 5) and species composition (table 5) are clearly moving toward those of the old secondary forest. These forests will eventually reach a stature similar to the old secondary forest and their biotic value rests in their potential as well as their advanced stage of recovery. Topographically, they buffer the Pterocarpus and old secondary forest (fig. 3c) and may be very important as protective agents to the two endangered forest ecosystems. More research is needed on forest regeneration and water relations to be able to pinpoint the interrelationships between the young and old secondary forests. The presence of endangered and endemic species in these stands adds to their biotic value. Because of the harshness of the soils on which they grow, it is difficult to predict how long it will be before these forests reach full maturity. This also requires more research.

An open disturbed forest and coconut groves are the remnants of a time when intensive human activity regulated forest areas on the site. These groves will also become mature forests, but their recovery is many times slower due to the more complete modification of the sites by humans. Their value at the present is confined to soil protection and, of course, the support of wildlife, as is evident in the case of the white-crowned pigeon colonies in the coconut grove.

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Changes in forest structure and area over a 44-year period in coastal moist forests in Puerto Rico show succession toward a single climax on white sands. A Pterocarpus forest has not changed and is considered a climax on flooded soils.

Keywords: Tropical forests, tropical succession, forested wetlands, Pterocarpus swamps.

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L-O-S-T: *L*ogging *O*ptimization *S*election *T*echnique

Jerry L. Koger and Dennis B. Webster

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SUMMARY

L-O-S-T is a FORTRAN computer program that can be used to quantify, analyze, and improve user selected harvesting methods. Harvesting times and costs are computed for road construction, landing construction, system move between landings, skidding, and trucking. Nonlinear harvesting relationships, irregular boundary shapes, nonuniform timber densities, unequal distances between multiple landings, variations in road construction conditions, changes in trucking speeds, and harvesting restrictions (environmental, physical, and time) can be analyzed. A linear programming formulation utilizing the relationships among marginal analysis, isoquants, and the harvesting methods is used to estimate and select the harvesting procedure having maximum profits.

ACKNOWLEDGMENTS

The linear programming algorithm used in L-O-S-T is a modification of one developed by Dr. A. Ravindran, Chairman and Professor, Department of Industrial Engineering, University of Oklahoma, Norman, Oklahoma. The input-output format modifications to Dr. Ravindran's program were made by E. Wade Culver, a computer engineer employed by the U. S. Forest Service at Auburn, Alabama, at the time of this study.

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L-O-S-T: *L*ogging *O*ptimization *S*election *T*echnique

Jerry L. Koger and Dennis B. Webster

INTRODUCTION

An age-old problem for timber harvesters is that of selecting the location for roads and landings that will maximize profits. This complex problem is partially due to: 1) nonlinear harvesting relationships, 2) nonuniform terrain and timber characteristics, 3) irregular tract boundaries with interior obstacles, and 4) the lack of a *general* mathematical expression describing total costs as a function of road densities, landing spacings, skidding distances, and equipment mixes.

Existing Solution Techniques

One of the earliest mathematical attempts to minimize harvesting costs was by Matthews (1942). To simplify the problem, he assumed: 1) the forest boundary could be approximated by simple geometric shapes, 2) linear cost relationships, 3) equal spacings between multiple landings, and 4) uniform slopes and timber densities. Using an indirect method, Matthews determined the optimum location of roads and landings by using calculus to obtain the minimum of unconstrained equations. Peters (1978) extended this approach by developing a direct method to determine optimum location of roads and landings. Although Peters used most of Matthews' assumptions, he included landing costs and used a mathematically accurate method developed by Suddarth (1952) for determining average skidding distance. Corcoran and Sammis (1975) developed a computer program to solve the road and landing spacing equations developed by Matthews. Their computer program solves two equations in two unknowns through a heuristically iterative procedure.

Operations research techniques were used very early by Lussier (1960, 1961) to minimize harvesting costs. He developed equations useful in determining the optimum number of landings, the distance between skid roads, and optimum skid road standards. Lussier also discussed several limitations on using a strictly mathematical approach and in making simplified assumptions in solving harvesting problems.

Gibson and Egging (1973) developed a location-allocation model for determining the optimal number and location of landings when using rubber-tired skidders. A truncated enumeration algorithm was used in the allocation phase to search systematically for a local optimum solution. Dynamic programming and a branch and bound methodology were used to find the global optimal solution.

Dykstra (1976) used mathematical and heuristic programming to determine the design of individual cutting units and the assignment of specific logging equipment to each cutting unit. He assumed that timber within each "type island" was homogenous and uniformly distributed and that only cable systems would be used to harvest timber on clearcuts. He also developed a digital model to portray topography, timber conditions, and harvest restrictions.

Carter et al. (1973) developed a computer model to determine the optimum spacings of roads and landings. Their work involved minimizing harvesting costs in the Rocky Mountain area where timber was accessible either by contour work-roads or switchbacks. An iteration solution technique was used to find simultaneous zero points of the partial derivatives of the road and landing spacing equations.

Several simulation models have been developed to analyze timber harvesting problems. However, most simulation models consider only a single landing and are not specifically developed to determine the optimum location of roads and landings. Several simulation models [Forest Harvesting Simulation Model (FHSM), Harvesting System Simulator (HSS), Simulation Applied to Logging Systems (SAPLOS), and Timber Harvesting and Transport Simulator (THATS)] were evaluated by Goulet et al. (1980).

Weintraub and Navon (1976) developed a mixed integer linear programming model to maximize dis-

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counted revenues from timber sales. Road construction and maintenance, timber management, and transportation were considered. The model was developed as a tool for decision in long range forest planning. Constraints were allowed on available capital, quantity of timber harvested, haul capacity of each road, and stand access. Kirby (1974) and Newnham (1975) also developed mathematical programming models useful in the long-range planning of harvesting operations.

Objectives

Existing techniques have provided useful insights into optimum timber harvesting strategies. For harvesting specific tracts of timber by ground-based skidding systems, these models are limited. Realistic harvesting costs often are not computed because overly simplified assumptions are made concerning stand boundary shapes, slopes, timber characteristics, and harvesting methods. The objectives of this study were to: 1) develop a computer program capable of determining realistic harvesting times and costs for highly individualistic conditions, and 2) utilize these harvesting times and costs, as well as harvesting constraints, in a unique linear programming formulation to obtain maximum profits. This FORTRAN computer model is titled L-O-S-T, an acronym for *l*ogging *o*ptimization *s*election *t*echnique.

HARVESTING FUNCTIONS OPTIMIZED

Although the methodology used to compute harvesting times and the linear programming formulation are *general*, the equations used to compute harvesting times are based on data collected in the Tennessee Valley Region (fig. 1). Harvesting times and costs are only calculated for road construction, landing construction, system move between landings, skidding, and trucking (fig. 2). Their relationships to selecting harvesting methods and the linear programming formulation are discussed in later sections. Costs are not calculated for felling, bucking, and loading (figs. 3 and 4) because those costs are not *assumed* to be significantly affected by the locations of roads and landings. The assumed general relationships among various harvesting activities and harvesting costs optimizations are shown in figure 5.

Road Construction

Construction of truck roads within the harvest boundary reduces skidding costs, but increases road construction, landing construction, system move, and trucking costs. In L-O-S-T, a road is considered as a low volume, temporary structure constructed solely for removing trees. If a high volume road is constructed with a design standard or life expectancy greater than that needed for timber harvesting, then the cost of the road must be adjusted to reflect only timber harvesting. The equation (A1, appendix 1) used to compute road construction times was developed by Koger (1978) from data collected in the Tennessee Valley Region.

Due to irregular terrain, construction conditions are seldom uniform over the entire road network. In order to determine more accurately construction costs, the road can be divided into short segments. These segments reflect differences in bank cubic yards, road slope (grade), or construction problems caused by rock or dense timber.

Although the number of bank cubic yards removed for making the roadbed is a variable, it does not have to be computed by the user. However, the user must supply roadbed width, side-hill slope, cut-slope ratio, and fill-slope ratio. This information is used in an equation reported by Bowman et al. (1975) to calculate bank cubic yards. Another variable, the number of acres in the road right-of-way, is also calculated for the user.

The construction of skid trails or skid roads for use by rubber-tired skidders is not computed in L-O-S-T. Skid road costs are assumed to be independent of the locations of truck roads and landings.

Landing Construction and System Move

Landings are usually constructed in conjunction with the road system, primarily as storage and loading areas for the skidded trees. Increasing landings decreases skidding costs, but increases system move, landing construction, and trucking costs. The equation used to compute landing construction times is a modification of the road construction equation (A1, appendix 1). The landing size in acres is converted to an "equivalent" road length based on an assumed cleared road width of 26.7 feet. An average cleared road width of 26.7 feet was observed in a study of logging roads in the Tennessee Valley Region (Koger 1978). A road construction condition factor of 3,000 is used (variable X6). In addition, the depth of the cut to level the landing site is assumed to be uniform across the landing area.

System move costs are those involved in moving equipment such as loaders, crawler tractors used for decking or landing maintenance, and shop trucks to the next landing. These costs are related to the distance and road condition between landings, the amount and type of equipment, and the hourly cost of the equipment and associated labor. Skidders may be included if they travel unloaded to the next landing site. Haul trucks are not included. If only one landing is used, system move costs are assumed to be zero. Move-in costs are not considered because they are

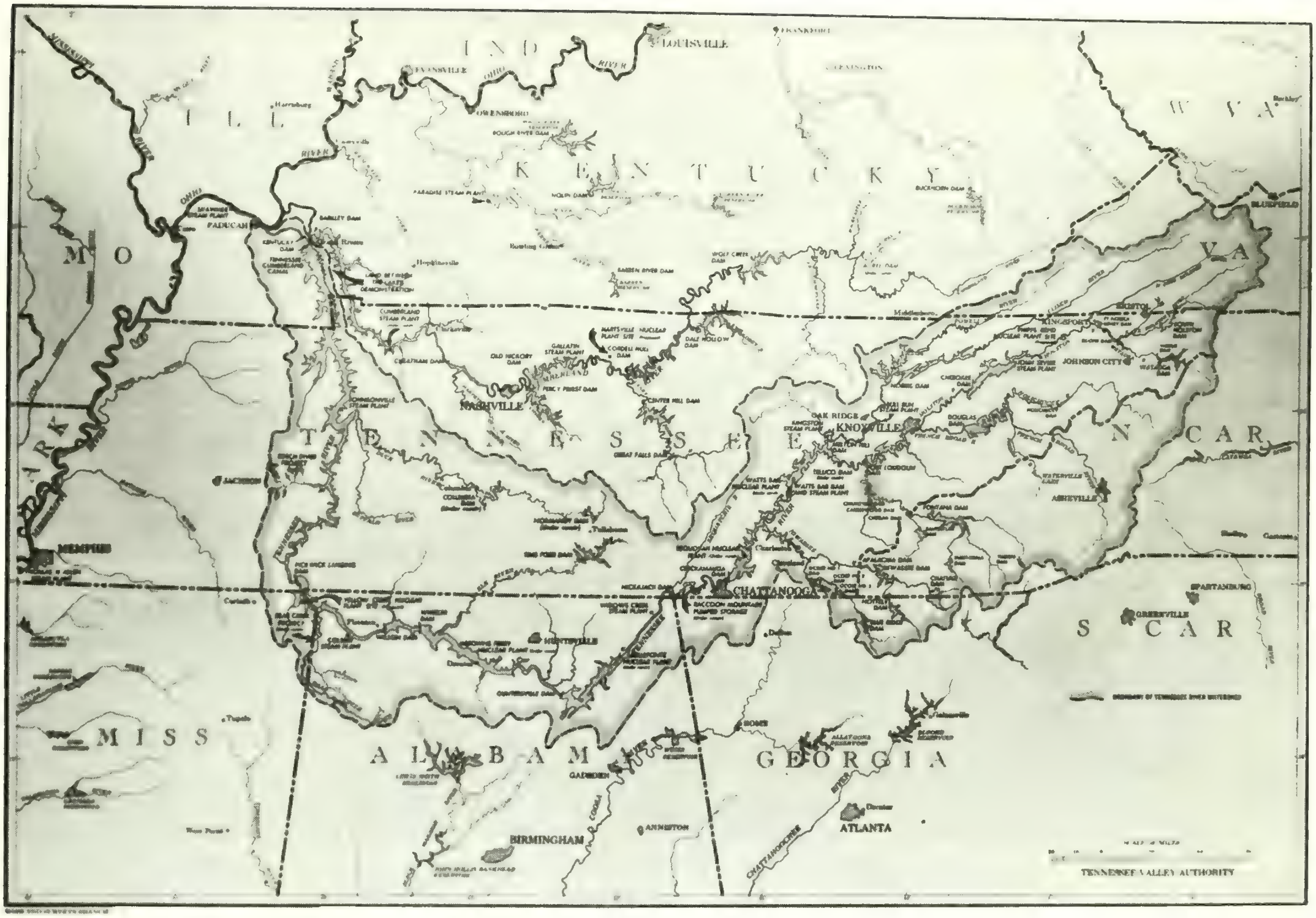

Figure 1.—*The Tennessee Valley Region (Tennessee, Kentucky, Virginia, North Carolina, Georgia, Alabama,* & Mississippi).

assumed to be approximately constant with whatever the locations of roads and landings.

In the linear programming formulation, landing construction and system move times are considered together. Since a relationship exists between these two costs, it is perhaps easier to think of them jointly rather than separately. Equation A5 (appendix 1) is used to compute a weighted time for landing construction and system move between landings.

Skidding

Skidding costs depend largely on skidding distance, which can be controlled through the locations of roads and landings. Skidding costs decrease as the density of roads and landings increases. The equation (A3, appendix 1) used to compute skidding times was developed by Koger (1976) for articulated, four-wheel drive, rubber-tired skidders operating in the Tennessee Valley Region. The range of observed volumes skidded in this region is shown in table 1 (appendix 1). Techniques available to compute average skidding distance are described in appendix 2. The differences among average skidding distance, the distance actually traveled by the skidder, and fixed skidding distance are also discussed.

Trucking

Trucking over roads within the harvest boundary reduces skidding costs but increases trucking, road construction, landing construction, and system move costs. The trucking speeds and load volumes shown in tables 2 – 4 (appendix 1) are based on data collected in the Tennessee Valley Region by Koger (1981). With respect to the optimum location of roads and landings, it is not necessary to compute trucking costs from the mill to the edge of the harvest boundary. This distance remains constant and is not affected by the road density or trucking pattern inside the harvest boundary. However, trucking costs are computed from each landing to the mill or delivery point because calculating these costs: 1) does not change the optimum location of roads and landings, 2) may alert the user to consider other routes from the mill to the harvest boundary, and 3) provides the user with an estimate of total trucking costs.

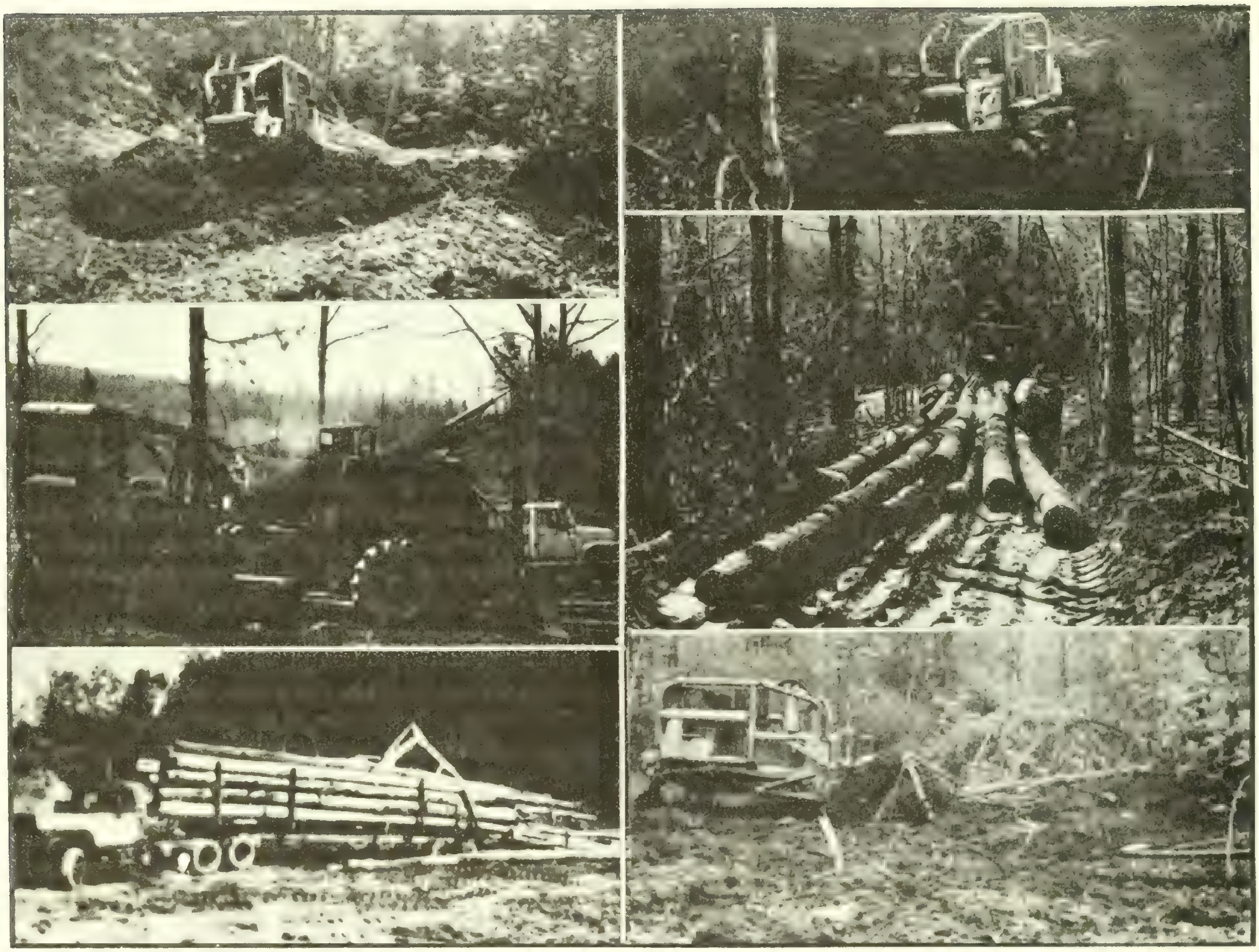

Figure 2.—*Truck road construction, system move between landings, skidding, trucking, and landing construction times are computed in L-O-S-T.*

SELECTING HARVESTING METHODS

Method Selection

The user must determine either two, three, or four different—but realistic—harvesting methods. These different methods can be viewed as harvesting or transportation plans. As a rule this requires drawing the boundary, stand densities, harvesting restrictions, road and landing locations, and skidding patterns on a topographic map. The methods should be selected so that road density (or road length) is at a minimum for the first method and at a maximum for the last method. Intermediate methods should be between these limits. Truck roads can be divided into segments to reflect differences in sidehill slope, road slope (grade), road width, or other construction factors. The size, construction condition, and distance from the harvest boundary is needed for each landing. The skidding pattern must be determined for each area and all landings. An area is a subdivision of a stand and its boundary is used in determining average skidding distance. Areas should be numbered consecutively within a stand and numbered so that no two areas have the same area number. An area can be subdivided into two or more new areas to reflect changes in skidding patterns among landings for different methods. The complexity of harvesting problems and the level of detail or realism required by the user is reflected in the number of areas selected.

Types of Harvesting Plans

L-O-S-T is capable of analyzing most ground-based plans including: 1) single road extension, 2) variable landing spacings along a fixed road length, 3) parallel roads, 4) multiple contour roads, 5) spur road extensions from major roads, and 6) climbing roads with switchbacks. The only requirement for analyzing any harvesting plan is that some relationship of road

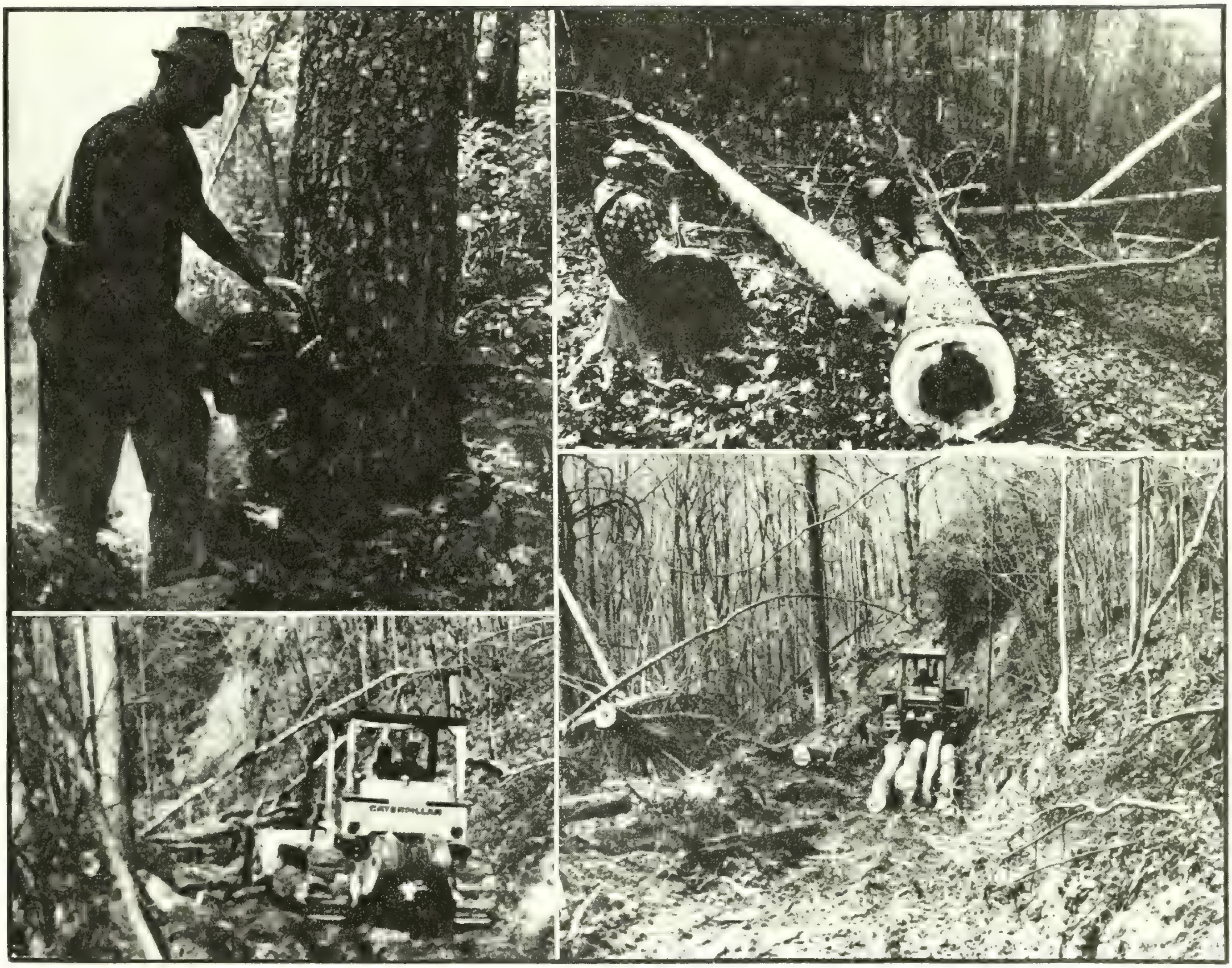

Figure 3.—*Felling, bucking, skid road construction, and bunching times are not computed in L-O-S-T.*

length and skidding exists between adjacent harvesting methods. From a silviculture perspective these harvesting plans could be for individual tree selection, group selection, diameter limit, financial maturity, or clear cuts. Once a cutting practice has been selected for an area in one method, it must remain the same in all the remaining methods. More than one different cutting practice may be used within a stand or harvest boundary.

OPTIMIZATION METHODOLOGY

Linear Programming Formulation

After the hours required for road construction, landing construction, system move between landings, skidding, and trucking have been calculated for each method, they are utilized in a linear programming formulation (equations 1 – 6). The formulation determines the proportion (λ) of each method that should be used. The formulation used in L-O-S-T is a slight modification of McCarl's (1979) and is also very similar to those developed by Allen (1956) and Chiang (1974).

$$\text{Maximize:} \quad Z = PQ_0 - \Sigma C_i H_i \qquad (1)$$

$$\text{Subject to:} \quad Q_0 - \Sigma Q_m \lambda_m \leq 0 \qquad (2)$$

$$\Sigma X_{im} \lambda_m - H_i \leq 0 \qquad (3)$$

$$Q_0 = Q_m \qquad (4)$$

$$\Sigma \lambda_m = 1 \qquad (5)$$

$$H_i \leq b_i \qquad (6)$$

$$Q_0, Q_m, \lambda_m, H_i \geq 0$$

where: Z = objective function

P = delivered price of the harvested timber (ie. $/1,000 board feet)

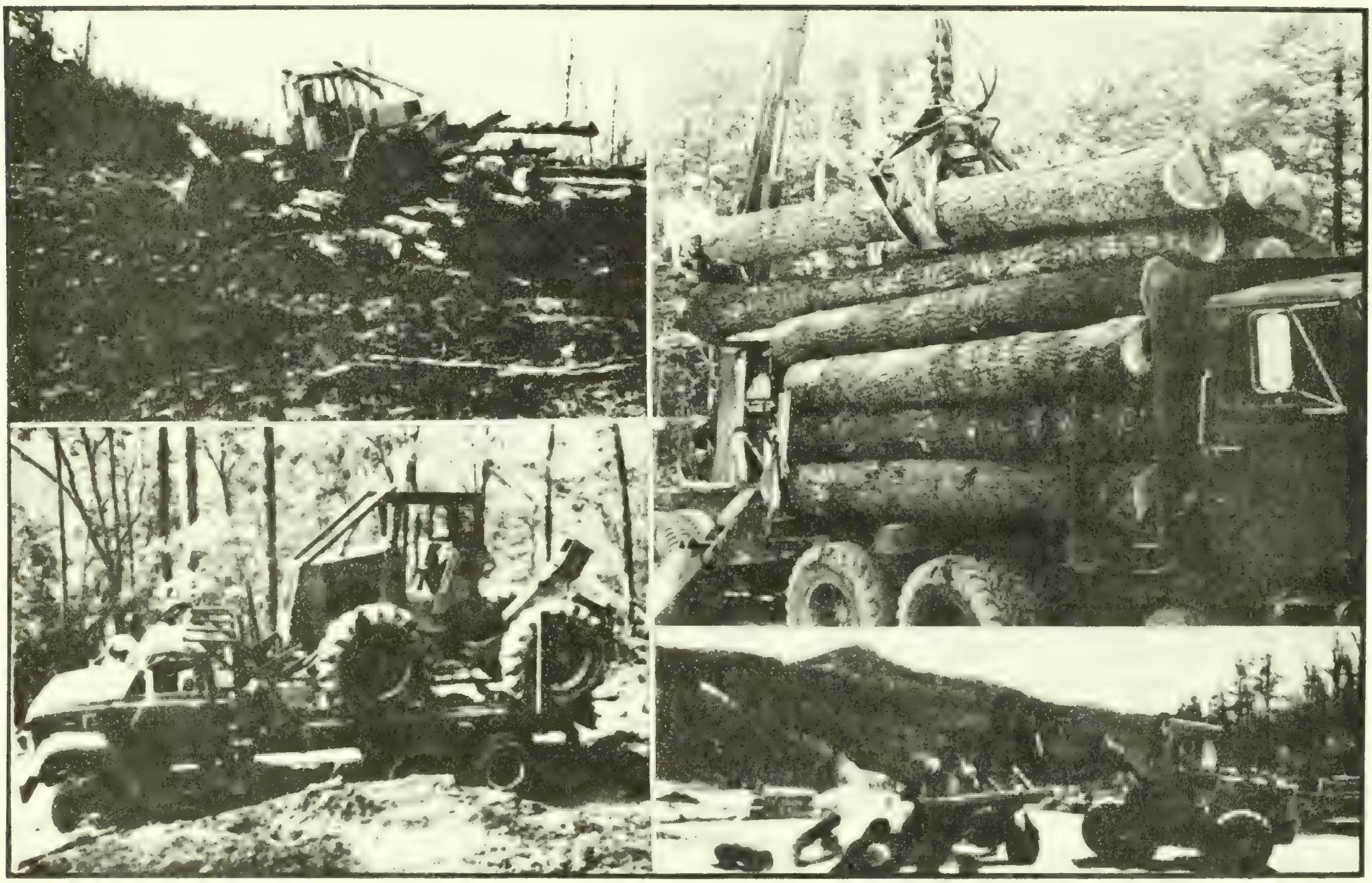

Figure 4.—*Decking, loading, move-in, and unloading times are not computed in L-O-S-T.*

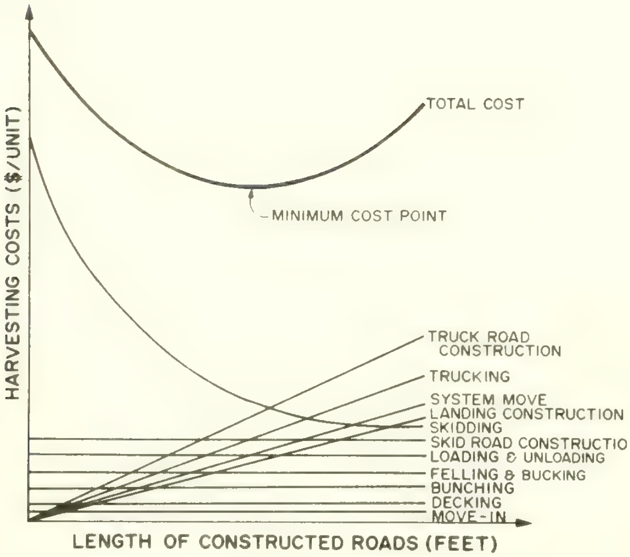

Figure 5.—*Assumed harvest cost relationships with respect to the optimum location of roads and landings (Note: fixed costs lines are in an arbitrary order).*

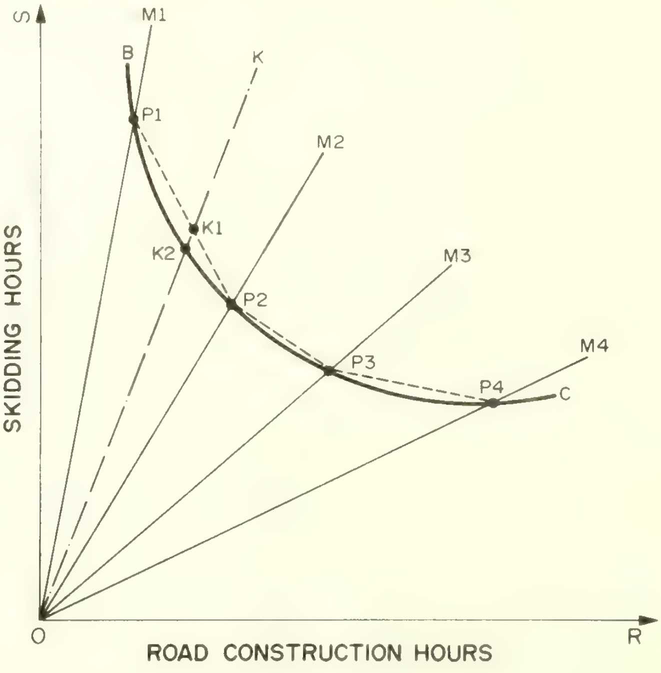

Figure 6.—*Relationships among isoquants, activity rays, and harvesting functions.*

Q_0 = volume of timber harvested (ie. board feet)
C_i = hourly equipment and labor cost for the i th activity (i = 1 for road construction, i = 2 for landing construction and system move, i = 3 for skidding, and i = 4 for trucking
H_i = the total number of hours of the i th activity used by all harvesting methods
λ_m = the proportion of the m th method used to harvest the total volume of timber (a decision variable)
X_{im} = the number of hours for the i th harvesting activity of the m th method
b_i = maximum number of hours allowed for the i th harvesting activity

Formulation Explanation

The relationships among the formulation (equations 1 – 6), harvesting times, and harvesting methods are shown in figure 6. Assume that a boundary of timber can be harvested by one of four methods (M1, M2, M3, or M4). For simplicity in graphing, only the harvesting activities of skidding (the hours required are mapped on the OS axis) and road construction (the hours required are mapped on the OR axis) will be considered. The volume of timber harvested is constant and represented by the isoquant BC. Fewer hours of skidding are required as the hours of road construction increases. The harvesting methods can be considered as activity rays (OM1, OM2, OM3, & OM4) with four activity vectors:

$$P1 = \begin{bmatrix} S1 \\ R1 \end{bmatrix} \quad P2 = \begin{bmatrix} S2 \\ R2 \end{bmatrix} \quad P3 = \begin{bmatrix} S3 \\ R3 \end{bmatrix} \quad P4 = \begin{bmatrix} S4 \\ R4 \end{bmatrix}.$$

Each activity vector shows a distinct input ratio capable of yielding a constant volume of harvested timber (isoquant BC). Thus, P1 indicates that method 1 (M1) is used to harvest all of the timber. This formulation assumes that it is also possible to harvest timber in various convex combinations such as: (¼P1 + ¾P2).

This means that a new method can be determined which uses ¼ of the skidding hours of method 1, plus ¾ of the skidding hours of method 2, plus ¼ of the road construction hours of method 1, plus ¾ of the road construction hours for method 2. Graphically, this means that the ratios for the combined processes must lie on the dashed line segments (P1P2, P2P3, P3P4). Assume that the optimum combination of skidding and road construction hours is at point K1 on activity ray OK. Due to the convex nature of the production function represented by the isoquant BC, point K1 is not on BC. The difference between K1 and K2 on the activity ray OK represents the error involved in attempting to solve a nonlinear convex production function with a linear approximation. This error is not considered to be significant; its relationships to the formulation, harvesting methods, and harvesting costs are shown in figure 7. The formulation will pick only one method or a linear convex combination of adjacent methods (Allen 1956; Chiang 1974).

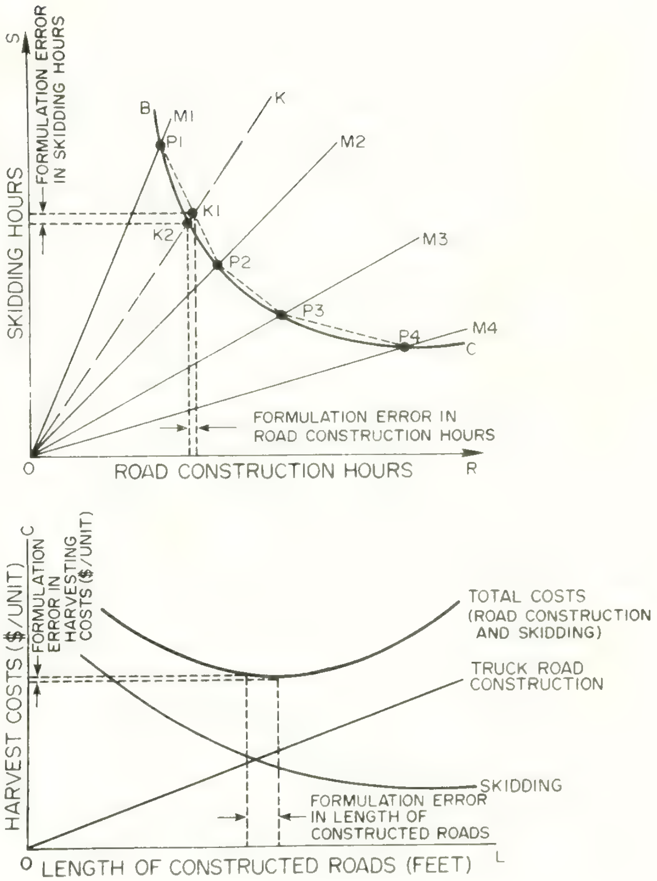

Figure 7.—*Error relationships involved in using the formulation.*

The assumptions of linear programming (additivity, linearity, divisibility, finiteness, and single-value expectations) are basically those used in the traditional marginal analysis of the firm. For timber harvesting, a specific method has a constant and linear proportionality between hours worked and volume harvested. Fractional hours worked can result in a fractional volume harvested. Finiteness means there are limits to the number of hours permitted to harvest a boundary of timber. The single-value expectation assumption assumes realistically that the quantity of timber harvested and its selling price is known. Another basic assumption is that the volume of timber harvested is not dependent on the harvesting method. This results in a fixed output independent of the number of hours required for road construction, landing construction, system move, skidding, and trucking.

HARVESTING EXAMPLE PROBLEM

Problem Description

An example problem has been developed to help illustrate the procedures used to select different harvesting methods, data input requirements, linear programming formulation, and program output. Specifically, the problem is to maximize profit by determining the least cost harvesting method for the boundary of timber shown in figure 8. The timber is to be harvested by a crawler tractor, two rubber-tired, cable skidders, and two trucks (table 5, appendix 3). Selected equipment weight and horsepower characteristics are given in appendix 4. The problem is sufficiently realistic to be interesting and complex enough to prevent the formulation of a *general* mathematical expression that could be differentiated to obtain minimum costs. The complexity of the problem is increased by: 1) an irregular boundary, 2) nonuniform timber densities or timber stands (fig. 9), 3) elevation changes, 4) restrictions on streambed crossings, 5) unequal costs for different road segments and landings, 6) unequal distances between landings, 7) nonlinear skidding costs, 8) decreases in truck travel speeds as the length of the road constructed inside the harvest boundary increases, and 9) restrictions on the time permitted for road construction (120 hours) and skidding (600 hours).

Harvesting Methods for the Example Problem

For the first method, a woods road was constructed 350 feet inside the harvest boundary and one landing constructed at location A (fig. 10). All the areas were skidded to this landing. Compared to the other methods, this method minimizes costs for road construction, landing construction, trucking, and system move, but maximizes skidding costs. For the second method, a woods road was constructed 2,525 feet inside the harvest boundary and landings constructed at locations A and B (fig. 11). Areas 1, 3, and 4 were skidded to landing A and the remaining areas skidded to landing B. It is important to recognize that areas can be subdivided to reflect changes in skidding patterns for different methods. For example, area 2 used in method 1 was subdivided into areas 3 and 6 for method 2. Area 3 was skidded to landing A, but area 6 was skidded to landing B. For the third method, a woods road was constructed 3,875 feet inside the harvest boundary and landings constructed at locations A, B, and C (fig. 12). Areas 1, 3, and 4 were skidded to landing A and areas 5, 6, 7, 8, and 9 skidded to landing B. The remaining areas were skidded to landing C. For the fourth method, a woods road was constructed 6,775 feet inside the harvest boundary and landings constructed at locations A, B, C, and D (fig. 13). Areas 1, 3, and 4 were skidded to landing A; areas 5, 6, 7, 8, and 9 to landing B; areas 10, 11, 15, and 19 to landing C; and areas 16, 17, 20, 21, 22, and 23 to landing D. Area 18 in methods 1 – 3 was subdivided into areas 19 and 20 to reflect changes in skidding patterns for method 4. Compared to other methods, this method minimizes skidding costs, but maximizes road construction, landing construction, system move, and trucking costs. A summary of several calculated and assumed values for each of these methods is given in appendix 3 (tables 6 – 11).

Data Input

For each method selected, specific input information is required on road construction, landing construction, system move between landings, skidding, trucking, and equipment costs. Sixteen data "card

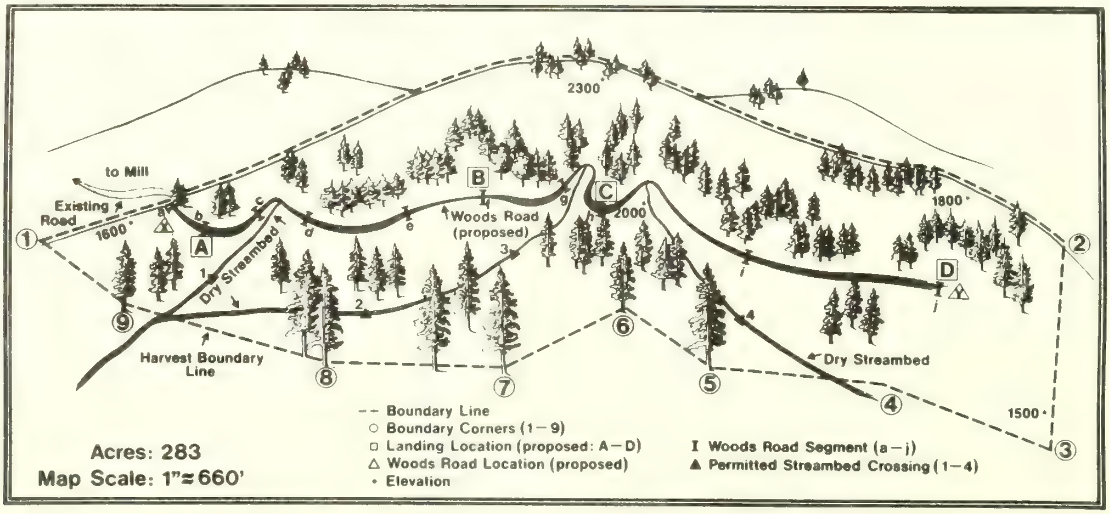

Figure 8.—*Harvesting example problem.*

types" are required for each analysis of a boundary of timber to be harvested. An additional card type is required if constraints are placed on the number of hours allowed for any of the pertinent harvesting activities. These different card types are described in detail in appendix 5. The complete input data used to analyze the hypothetical example is shown in appendix 6. The values shown for average skidding distance were based on the harvest patterns for the different areas and landing locations in figures 10 – 13. Average skidding distances were determined using a BASIC program written for use on an HP 9830A[1] calculator and HP 9864A digitizer.

Output Analysis

The computer output for the harvesting example problem is shown in appendix 7. The output consists of: 1) an echo check of the input data, 2) harvesting times and costs, and 3) the linear programming solution and sensivity analysis.

Road construction times and costs, the number of bank cubic yards, and acres cleared for the road-right-of-way are given for each segment. Road construction costs are: $170 for method 1 ($2,565 per mile); $1,061 for method 2 ($2,219 per mile); $1,625 for method 3 ($2,214 per mile); and $2,910 for method 4 ($2,268 per mile). The easiest way to modify road construction costs without changing the road design or road construction equipment characteristics is through the input variable ROADTY (card type 10, appendix 5). Although guidelines are provided for estimating ROADTY, a value should be selected that gives reasonable cost estimates based on the user's experience or modeling needs.

Landing construction and system move times and costs are computed for each landing. Landing construction costs are: $56.27 for method 1; $89.64 for method 2; $118.73 for method 3; and $150.83 for method 4. The simplest way to influence landing construction costs without changing the landing design or landing construction equipment characteristics is through the input variable EFFL (card type 12, appendix 5). System move costs are: $0.0 for method 1; $101.26 for method 2; $192.39 for method 3; and $303.78 for method 4.

Skidding times and costs are computed for each skidder on each area and summarized by area, landing, and method. The number of cycles and average cycle time are also given. The skidding costs are: $28,769.13 for method 1; $18,076.16 for method 2; $15,471.31 for method 3; and $10,950.56 for method 4. The easiest way to modify skidding times without changing skidder characteristics, skid load volumes, or skidding distances is through the input variable, AD (card type 13, appendix 5).

In addition to skidding times and costs, average skidding distance, fixed skidding distance, and weighted actual travel skidding distances are summarized by landing and method. In most cases the greatest potential for reducing skidding times is through a reduction of average *fixed* skidding distance. In the harvesting example problem, average skidding distance only decreased from 686 feet for method 1 to 550 feet for method 4. However, average fixed skidding distance decreased form 4,296 feet for method 1 to 759 feet for method 4. This drastic reduction in average fixed skidding distance was largely responsible for skidding times decreasing from 659.75 hours for method 1 to 264.83 hours for method 4. Weighted average travel skidding distance is computed by mul-

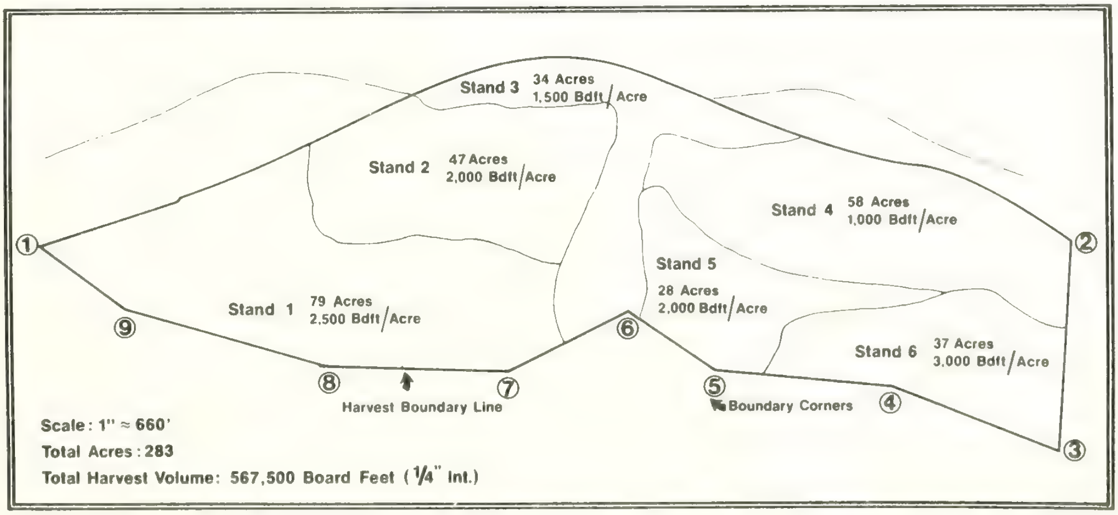

Figure 9.—*Stand densities and acres for the harvesting problem.*

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[1] The use of trade or corporate names is for reader association and convenience. Such does not constitute an official evaluation, conclusion, recommendation, endorsement, or approval of any product or service to the exclusion of others which may be suitable.

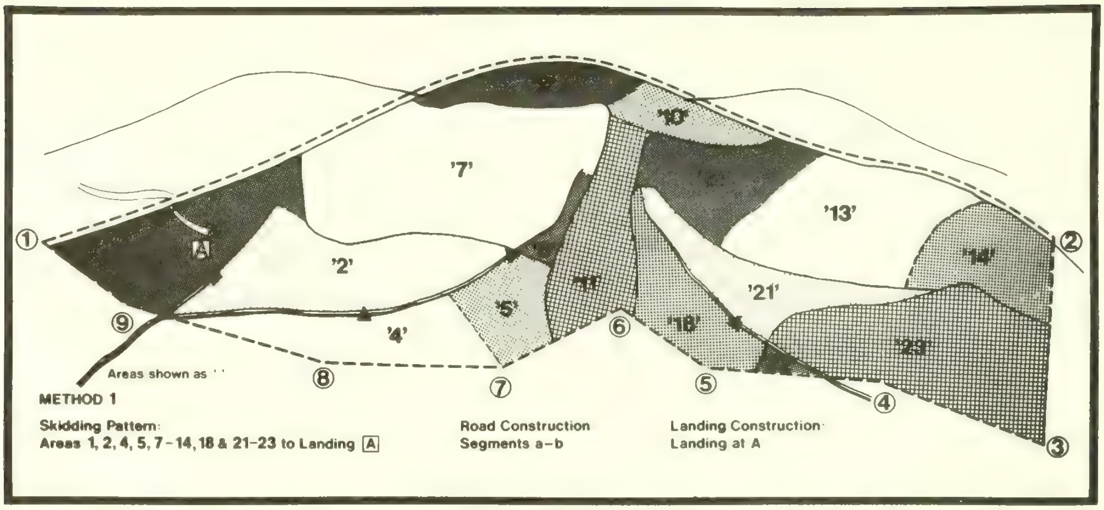

Figure 10.—*Road, landing, and area locations used in method 1.*

tiplying average skidding distance by the skidding correction factor for each area. This product is added to to the fixed skidding distance on each area and then multiplied by the volume for that area in order to obtain a weighted value.

The number of acres and volume of timber harvested for each method are provided as information and as checks on the accuracy of data input. The number of acres for each method must be the same and the volume harvested for each method must be the same. In this example, 283 acres and 567,500 board feet (¼″ Int.) were harvested for each method. The linear programming formulation requires that an equal volume of timber be harvested in each method.

Trucking times and costs are shown for each truck and are summarized by landing and method. In addition, cycle times and number of loads required for each truck are given. Trucking costs for each method are: $17,182.48 for method 1; $17,913.40 for method 2; $18,277.16 for method 3; and $18,774.91 for method 4. In this case the construction of four landings and 6,775 feet of woods roads only increased trucking costs by $1,592.43.

A method summary giving the hours, costs per harvesting unit for each function, total costs, and total costs per harvesting unit is provided in the output. The total harvesting costs per thousand board feet (¼″ Int.) for road construction, landing construction and system move, skidding, and trucking are: $81.37 for method 1; $65.62 for method 2; $62.79 for method 3; and $58.31 for method 4. The hours required for each harvest function considered in L-O-S-T are shown in table I and are used to illustrate a numerical example of the linear programming formulation (equations 7 – 16). The formulation can also be seen in the output (appendix 7) as the first iteration of the linear programming tableaus.

Table I.—*Harvest hours for the four methods*

Harvest Function	Method 1 (hours)	Method 2 (hours)	Method 3 (hours)	Method 4 (hours)
Road construction	7.86	49.07	75.12	134.55
Landing construction & system move	0.78	2.64	4.31	6.29
Skidding	695.75	437.15	374.16	264.83
Trucking	429.56	447.83	455.68	469.37

After 18 iterations the optimum linear programming solution consisted of 24% of method 3 and 76% of method 4. The optimum method (not a global optimum) used 120 hours of road construction, 5.8 hours of landing construction and system move, 292 hours of skidding, and 466 hours of trucking. The linear programming solution does not give the exact physical location of the roads, landings, and skidding patterns. However, the output can be used to help locate the road, landings, and skidding patterns for a new method consisting of 24% of method 3 and 76% of method 4. Since 102.2 hours were required to construct the road to the end of segment h-i, then 17.8 hours (120.0-102.2) or 909 feet of segment i-j can be constructed. The road should be constructed 2,159 feet beyond landing C. Landing D would be located 6,034 feet from the harvest boundary; whereas it was originally located 6,775 feet. The skidding patterns would stay the same for landings A and B, and probably C. However, the skidding patterns would change for landing D. If another computer analysis were made in order to obtain a better estimate, then meth-

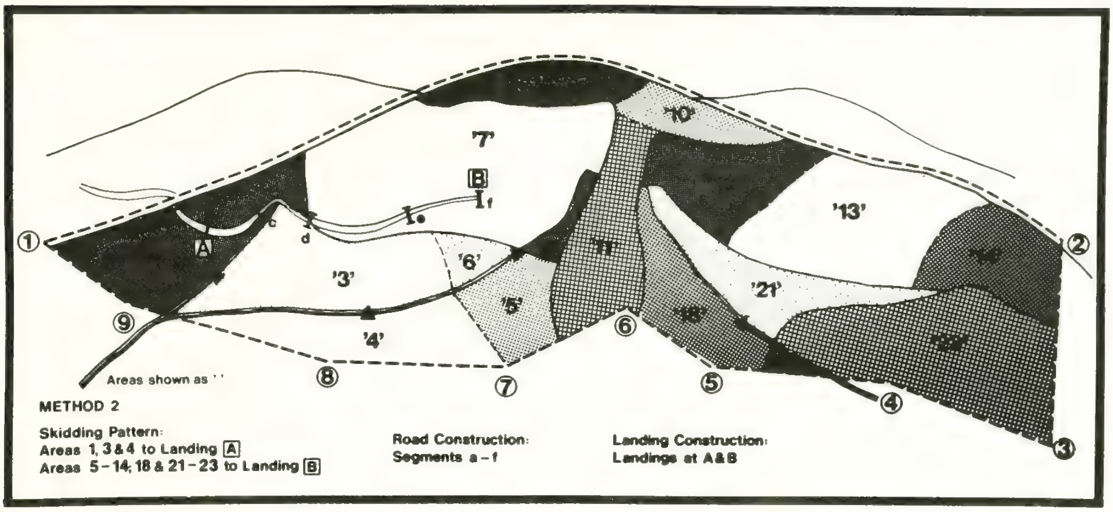

Figure 11.—*Road, landing, and area locations used in method 2.*

Linear programming equations for the harvesting example problem:

Maximize Z:

$$
\begin{array}{rrrrrrrrrcll}
\$95.00\ Q_0 & & & & & -\$21.63\ H_1 & -\$72.26\ H_2 & -\$41.35\ H_3 & -\$40.00\ H_4 & & & (7) \\
1.00\ Q_0 & -567.50\ \lambda_1 & -567.50\ \lambda_2 & -567.50\ \lambda_3 & -567.50\ \lambda_4 & & & & & \leq & 0.00 & (8) \\
 & 7.86\ \lambda_1 & 49.07\ \lambda_2 & 75.12\ \lambda_3 & 134.55\ \lambda_4 & -1.00\ H_1 & & & & \leq & 0.00 & (9) \\
 & 0.78\ \lambda_1 & 2.64\ \lambda_2 & 4.31\ \lambda_3 & 6.29\ \lambda_4 & & -1.00\ H_2 & & & \leq & 0.00 & (10) \\
 & 695.75\ \lambda_1 & 437.15\ \lambda_2 & 374.16\ \lambda_3 & 264.83\ \lambda_4 & & & -1.00\ H_3 & & \leq & 0.00 & (11) \\
 & 429.56\ \lambda_1 & 447.83\ \lambda_2 & 455.68\ \lambda_3 & 469.37\ \lambda_4 & & & & -1.00\ H_4 & \leq & 0.00 & (12) \\
1.00\ Q_0 & 0.00\ \lambda_1 & 0.00\ \lambda_2 & 0.00\ \lambda_3 & 0.00\ \lambda_4 & & & & & \leq & 567.50 & (13) \\
 & & & & & & & & & & \text{(volume)} & \\
 & 1.00\ \lambda_1 & 1.00\ \lambda_2 & 1.00\ \lambda_3 & 1.00\ \lambda_4 & & & & & \leq & 1.00 & (14) \\
 & & & & & & & & & & \text{(methods)} & \\
 & & & & & 1.00\ H_1 & & & & \leq & 120.00 & (15) \\
 & & & & & & & & & & \text{(road construction)} & \\
 & & & & & & & 1.00\ H_3 & & \leq & 600.00 & (16) \\
 & & & & & & & & & & \text{(skidding)} &
\end{array}
$$

where: $Q_0, \lambda_m, H_i \geq 0$

ods 1 and 2 should be eliminated. Two new methods should be selected between the original methods 3 and 4. The original method 3 would become the new method 1. By keeping two of the original methods, the amount of new input data needed is reduced and the search area can be systematically analyzed.

Harvesting costs for the optimum method were \$59.41 per thousand board feet (¼″ Int.). If the constraint on road construction (120 hours) were not binding, then all of method 4 could have been used and harvesting costs would have been \$58.31 per thousand board feet. Binding constraints always cause an increase in costs. However, the optimum method selected by the linear program (24% of method 3 and 76% of method 4) is still better than the method 1 (\$81.37), method 2 (\$65.62), or method 3 (\$62.79).

The sensivity analysis in L-O-S-T consists of penalty costs, shadow prices, and ranges on all the cost coefficients and constraints. The formulation used in L-O-S-T and the original input format of the linear program algorithm make it difficult to correlate the variable codes in the sensivity analysis with the correct harvesting costs and constraints. However, users familiar with sensivity analysis should be able to interpret these results in L-O-S-T. In this formulation shadow prices are always zero because all the timber can be harvested by the number of hours computed for each method. The hourly costs of the harvesting functions are always non-basic. In this example, the hourly cost of road construction can increase from \$21.63 to \$64.43 without changing the optimum solution. This implies that the same road could have been constructed to a higher standard or that more roads should be constructed. The method summary costs also indicated that more roads and landings should be constructed.

LIMITATIONS

The linear programming solution calculated in L-O-S-T is not a global optimum or the absolute best of all possible harvesting methods. The program determines the "best" method based on the methods supplied by the user. Equipment interactions resulting in production delays are not calculated by the program. The effects of equipment interactions must be supplied indirectly by the user through equipment efficiency and area difficulty factors. Harvesting costs are calculated only for road construction, landing construction, system move between landings, skidding, and trucking. While this does not limit the optimization process, an estimate of total harvesting costs is not provided.

EXECUTING L-O-S-T

L-O-S-T is written in FORTRAN IV and is being run under WATFIV on an IBM 3031 at Auburn University. With a modest amount of additional effort, the program could be converted for use on similar computer systems. The example problem described in this report required 264K of storage, used 3.38 seconds of CPU time, and cost about one dollar to run. The FORTRAN source statements used in L-O-S-T are shown in appendix 8. A punched and interpreted source deck (1,914 cards) can be obtained from: Engineering Research Unit, G. W. Andrews Forestry Sciences Laboratory, U. S. Forest Service, Devall Street, Auburn University, Alabama 36849. Phone (205) 887-7542, (FTS) 534-4518.

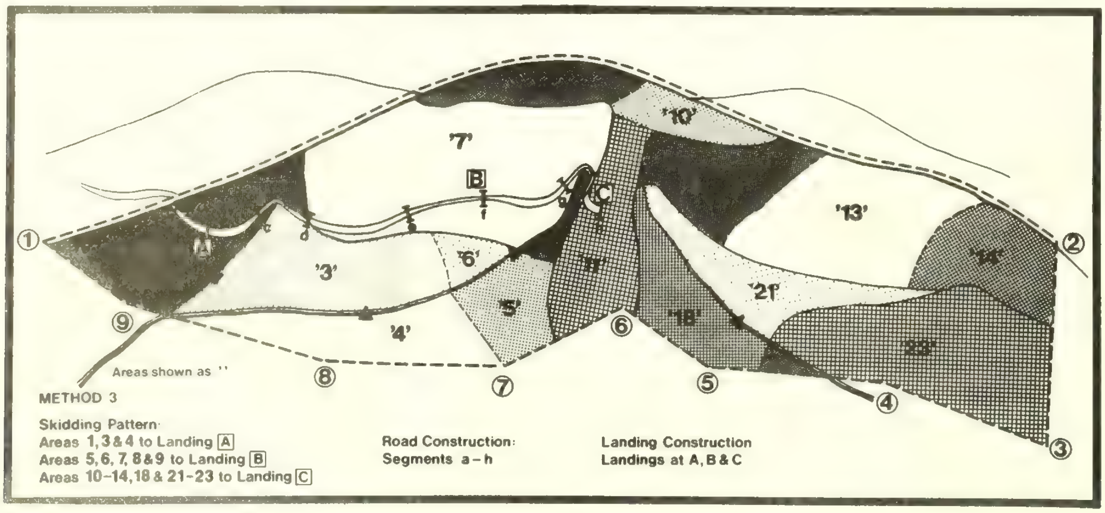

Figure 12.—*Road, landing, and area locations used in method 3.*

RESULTS AND DISCUSSION

A two-part methodology has been developed to analyze user selected harvesting methods. The first part of this methodology considers very specific and realistic harvesting conditions: terrain features, boundary shapes, roads, landings, skidding patterns, and environmental restrictions. Harvesting times and costs are computed for road construction, landing construction, system move between landings, skidding, and trucking. The second part of the methodology uses these harvesting times in a linear programming formulation. The formulation utilizes the relationships among the harvesting methods to estimate and select the harvesting procedure having maximum profits.

Since the analysis performed by L-O-S-T depends on the harvesting methods selected by the users, it is important that users have some knowledge and experience in developing harvesting plans. Time and effort spent in selecting realistic harvesting plans will enable the output from L-O-S-T to be used with greater confidence by managers of harvesting operations.

L-O-S-T does not provide a global optimum with each computer analysis. Theoretically, the procedures used would, through repeated computer runs, find the ultimate harvesting method having maximum profits. L-O-S-T does provide a local optimum and a wealth of information for selecting a better harvesting method. Searching for the elusive global optimum has some academic merit; however, selecting feasible harvesting plans and then systematically quantifying, analyzing, and improving them has greater practical applications.

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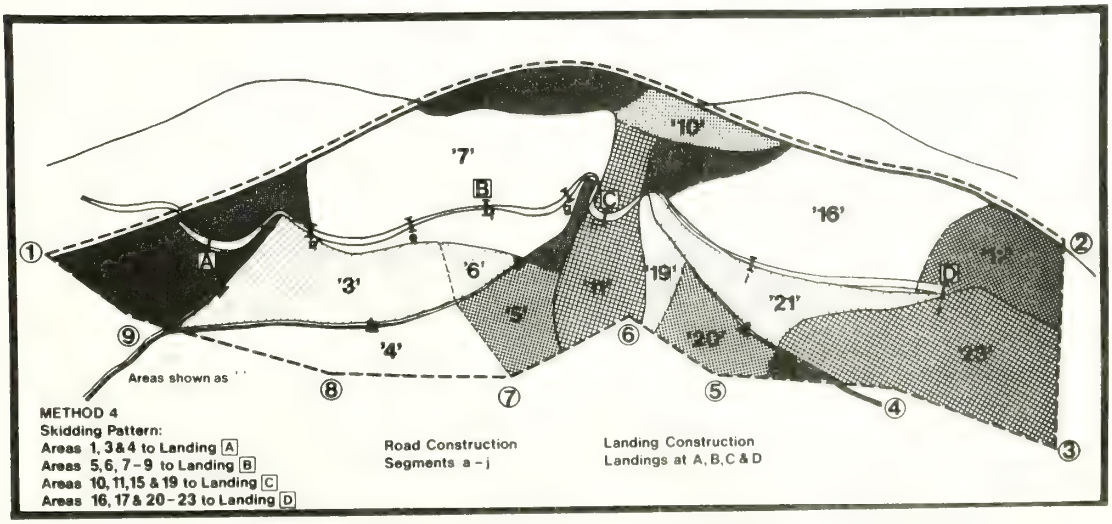

Figure 13.—*Road, landing, and area locations used in method 4.*

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Appendix 1—Harvesting Equations, Data, and Cost Relationships

HARVESTING EQUATIONS AND DATA

road construction equation: (Koger, equation 3, pg 30, 1978)

$$T = \frac{\frac{X1}{X6}\left[0.524\left[X2/(X3X4) \right]^{0.5} + 12.668\left[X5/(X3X4) \right]^{0.5} \right]}{X7} \qquad \text{(A1)}$$

where: T = predicted road constructed time in hours
X1 = road length in feet
X2 = number of bank cubic yards per 1,000 feet of road length
X3 = slope correction factor estimated by:

$$1.000 - (\%\ \text{road slope}/100) - 0.0001952\ (\%\ \text{road slope}/100)^2$$

note: % road slope (+, -) is in direction of road construction

X4 = net horsepower of crawler tractor (Table 12, Appendix 4)
X5 = number of acres of cleared road width per 1,000 feet of road length
X6 = road construction difficulty factor with suggested values of:
10 for high volume truck road or low volume road constructed adverse conditions
500 for low volume truck road constructed under average conditions
1,000 for low volume skid road constructed under average conditions
2,000 for upgrading existing low volume skid road under average conditions
3,000 for low volume landing constructed under average conditions

note: intermediate values (ie. 520, 750) can be used

X7 = (equipment availability)(equipment utilization), with suggested values of:
0.50 for low availability and utilization
0.85 for average availability and utilization
0.95 for high availability and utilization

note: only the variables X1, X4, X6, and X7 are required as user supplied inputs. The variables X2, X3, and X5 are calculated by the program.

__rubber-tired skidder equation__ (Koger, equation 2, pg 31, 1976)

T = (travel empty + travel loaded + fixed cycle time)/efficency (A2)

$$T = \left[\frac{0.0584037\, A^{a} B^{b} C^{c} (1+D)^{d} E^{e} (1+\sin(F))^{f} G^{g}}{H^{h} I^{i}} + \frac{0.00005166\, J^{j} A^{k} B^{l} (1+D)^{m} E^{n} [1+\sin(-F)]^{o} G^{p}}{H^{q} C^{r} I^{s}} + K \right] \frac{1}{L} \tag{A3}$$

where: T = cycle time in minutes
A = one-way skidding distance in feet
B = radius of curvature in feet (used average study value of 483.99)
C = net skidder horsepower (Table 13, Appendix 4)
D = rut depth in inches (used average study value of 6.26)
E = harvest elevation in feet (used average study value of 1,547.13)
F = trail slope in degrees(measured in travel loaded direction)
G = empty skidder weight in pounds (use constant of 20,400)
H = cone index of soil (used average study value of 192.23
I = arc length in feet (used average study value of 131.59)
J = board feet per cycle (1/4 " Int.)
K = fixed time per cycle in minutes for hooking, decking, etc.
L = (equipment availability)(equipment utilization), or equipment efficiency

exponents a through s:
a=1.022449; b=3.549048; c=1.317563; d=0.223969; e=0.180727
f=2.156775; g=0.177384; h=0.183381; i=6.943695; j=0.110305
k=1.098034; l=3.472234; m=0.116935; n=0.098604; o=0.681159
p=3.234567; q=0.067053; r=3.157504; s=7.456998

note: Variables B, D, E, G, H, and I remain constant in the program and do not have to be supplied as inputs by the user.

Table 1.--Observed skidding volumes by horsepower*

Horsepower	VOLUME PER CYCLE WHEN MEASURED AS:											
	Pounds			Board Feet:¼" Int.			Cubic Feet			Cords		
	Low	High	Mean	Low	High	Mean	Low	High	Mean	Low	High	Mean
70	2,205	7,080	5,266	87	617	410	29	117	83	0.38	1.21	0.90
80	3,141	7,129	5,278	233	741	471	43	120	81	0.54	1.21	0.90
92	4,032	6,921	4,987	350	666	464	67	108	82	0.69	1.18	0.85
94	815	19,188	8,124	23	2,403	861	14	294	119	0.14	3.28	1.39
112	2,983	25,450	8,416	141	2,260	715	51	361	128	0.50	4.35	1.44
120	5,005	20,226	12,822	503	2,142	1,334	81	310	199	0.86	3.46	2.19
147**	4,120	7,095	5,468	419	776	575	71	122	94	0.70	1.21	0.93
165**	4,808	5,503	5,155	445	522	484	83	95	89	0.82	0.94	0.88

* (Koger, Table 6, pg 22, 1976)

** Did not observe when stand conditions permitted high volume skidding.

trucking equation

The following equation is used to calculate truck cycle time from landings to the delivery point (mill).

$$Y_{ij} = \frac{O}{S_j} + \frac{O}{F_j} + \frac{X_i}{(E_j(1+C_i))/2} + \frac{X_i}{(L_j(1+C_i))/2} + K_j \qquad (A4)$$

where: Y_{ij} = round trip truck time in hours from the i th landing for the j th truck
O = one-way distance in miles over roads outside the harvest boundary
S_j = average empty travel speed in miles per hour for the j th truck over sections outside the harvest boundary (woods to mill)
F_j = average loaded travel speed in miles per hour for the j th truck over sections outside the harvest boundary (woods to mill)
X_i = distance in miles from beginning of harvest boundary to the i th landing
E_j = empty travel speed in miles per hour over the woods road for the j th truck
C_i = ratio of ending travel speed to beginning travel speed as measured from beginning of harvest boundary to the i th landing
L_j = loaded travel speed in miles per hour over the woods road for the j th truck
K_j = fixed time per cycle in hours for the j th truck

trucking data

Table 2.-- Average truck speed versus road type*

Type of Road	Average Empty Speed (mph)	Average Loaded Speed (mph)
Woods	8.34	5.35
Gravel	16.23	13.89
Two-lane blacktop	38.76	33.78
Interstate	55.00	45.82
City	23.97	21.44

* (Koger, Table 1, pg 5, 1981)

Table 3.--Load characteristic for trucks hauling logs (or tree-length stems)*

Truck Description	Average Number of logs	Average Length (feet)	Average Volume (Doyle)	Average Volume (1/4" Int.)
Single-Axle (1.5-ton)	18	13.6	1,313	1,752
Tandem-Axle (1 drag)	30	12.9	1,937	2,584
Tandem-Axle (2-ton)	25	13.0	2,018	2,693
Tri-Axle (1 drag)	35	15.2	2,643	3,526
Four-Axle (2-drag)	46	11.7	3,276	4,370
Tractor-Trailer (logs)	43	14.5	3,868	5,160
Tractor-Trailer (stems)	35	36.9	4,222	5,632

* (Koger, Table 2, pg 6, 1981)

Table 4.--Load characteristics for trucks hauling pulpwood (bolts, 21-foot stems, or tree-length stems)*

Truck Description	Type of Load	Average Volume (cords)
Single-Axle (0.75-ton)	Pulpwood bolts (5' 3")	1.5
Single-Axle (1-ton)	Pulpwood bolts	2.1
Single-Axle (1.5 ton)	Pulpwood bolts	4.6
Tandem-Axle (1 drag)	Pulpwood bolts	5.3
Tractor-Trailer	Tree-length	8.7
Tandem-Axle (2-ton)	21-foot stems	9.0
Tri-Axle (1 drag)	21-foot stems	9.3
Tractor-Trailer	Pulpwood bolts	9.8

* (Koger, Table 3, pg 6, 1981)

HARVESTING COST RELATIONSHIPS

Landing Construction and System Move

In the linear programming formulation, landing construction and system move times and costs are considered together. The following equation is used to compute a weighted time for landing construction and system moving.

$$WH = (SL + SM)/(HL + HM) \qquad (A5)$$

Where: WH = weighted number of hours for landing construction and system move
SL = sum of landing construction costs for this method
SM = sum of system move costs for this method
HL = hourly landing construction costs
HM = hourly system move costs

Multiple Equipment

In many cases multiple crawler tractors, skidders, or trucks may be used. For example, two rubber-tired cable skidders may be used on the same boundary to skid trees to the landings. Equation A6 is used to compute total time under these conditions. This equation is used for multiple equipment involved in road construction, skidding, or trucking, but not for landing construction. Only one crawler tractor is allowed to construct landings, although two or more are involved in road construction.

$$T = \frac{1}{\frac{1}{H_1} + \frac{1}{H_2} + \dots + \frac{1}{H_n}} \qquad \text{(A6)}$$

where: T = hours required if all equipment (ie. skidders) worked together
H_1 = hours required if this harvesting activity were done entirely by the first machine
H_2 = hours required if this harvesting activity were done entirely by the second machine
H_n = hours required if this harvesting activity were done entirely by the last machine

Equipment Interactions and Efficiency

Equipment interactions resulting in production delays are not directly considered. However, an equipment efficiency factor which considers utilization is available and can be used to model indirectly the effects of delays caused by equipment interactions. Equipment efficiency can be estimated or calculated by the following equation.

$$E = AU \qquad \text{(A7)}$$

where: E = equipment efficiency (decimal value greater than 0)
A = equipment availability (decimal)
U = equipment utilization (decimal)

Labor and Equipment Costs

Harvesting costs computed in L-O-S-T are based on only the harvesting functions considered in the optimization analysis (road construction, landing construction, system move between landings, skidding, and trucking). Hourly labor cost includes the base wage rate plus social security and workmen's compensation. Hourly equipment costs include fixed and operating costs based on a scheduled hour. Miyata (1980) discusses fixed and operating costs for timber harvesting equipment and provides several examples of the different methods available. The following equation reported by Nichols (1962) is a simple rule-of-thumb method that can be used to determine the approximate scheduled hourly cost of timber harvesting equipment used in L-O-S-T.

$$C = 0.0003(P) \tag{A8}$$

where: C = hourly equipment costs (excluding labor)
P = purchase price of equipment or purchase price of an equivalent piece of new equipment

Appendix 2—Determining and Using Skidding Distances

Determining Skidding Distance

In L-O-S-T, a distinction is made between average skidding distance (ASD), average travel distance (ATD), and fixed skidding distance (Figure I). The equations developed by Suddarth (1952) for average skidding distance on simple geometric shapes are shown in Figure II. Greulich (1980) extended this and included the influence of slope on the equations he developed for average skidding distance on areas with simple geometric shapes. For irregular shaped areas, average skidding distance can be accurately computed using a desk-top programmable calculator and digitizer (Peters and Burke 1972).

In most cases there is very little difference between the values obtained for average skidding distance using the mathematical equations derived by Suddarth (1952) and those obtained by determining the straight line distance from the landing to the centroid of the area. For example, if the landing is located at the corner of a mile square area, then the average skidding distance computed by Suddarth's equation is 4,040.23 feet. The straight line distance from the landing to the centroid (2640,2640) of the area is 3,733.52 feet. A simple graphical method for estimating average skidding distance on irregular shaped areas is shown in Figure III.

While average skidding distance has an exact mathematical definition (Suddarth 1952), its use, nevertheless, represents a simplification of the skidding process. If average skidding distance is used, then all the trees on the area are essentially assumed to be located an equal distance (average skidding distance) from the landing. However, trees are scattered over the area and skidding usually starts near the landing and proceeds to the farthest boundary of the harvest area. A more accurate estimate of skidding cycle time can be obtained by integrating the skidding equation (A3) over the range of skidding distances. Similarly, using an average skidding cycle volume rather than the range of cycle volumes causes equation A3 to underestimate skidding times. In L-O-S-T, users have the options of using average values for skidding distance and volume or their ranges. For simplicity reasons, the simplifed version (A10) of the skidding equation will be used to illustrate the integration procedures (A11) available in L-O-S-T, given below.

Y = travel empty time + travel loaded time + fixed time (A9)

$$Y = 0.0027(X)^{1.022} + 0.00088(X)^{1.098}(V)^{0.11} + K \tag{A10}$$

where: Y = cycle time in minutes for articulated, four-wheel drive, rubber-tired skidders in the 70 to 130 horsepower range
X = one-way skidding distance in feet
V = cycle volume in board feet (1/4 Int.); must be reasonable for skidder size and skid trail conditions (Table 1, Appendix 1)
K = assumed fixed time (minutes) per cycle for hooking, decking, etc.

$$Y = \frac{0.0027}{b-a}\int_a^b (X)^{1.022}\,dx + \frac{0.00088}{(b-a)(d-c)}\int_a^b\int_c^d (X)^{1.098}(V)^{0.11}\,dxdv + K \tag{A11}$$

where: Y = skidding cycle time in minutes
a = lower limit on skidding distance in feet
b = upper limit on skidding distance in feet
c = lower limit on skidding volume in board feet (1/4" Int.)
d = upper limit on skidding volume in board feet (1/4" Int.)
X = skidding distance, feet
V = skidding volume, board feet (1/4" Int.)
dx = derivative of Y with respect to X
dv = derivative of Y with respect to V
K = fixed time per cycle in minutes for hooking, decking, etc.

Actual Travel Distance

Due to terrain features (steep slopes, streams, rocks, soft ground) and to stand characteristics (large stumps, dead snags), the distance actually traveled by the skidder from the landing to the woods is rarely ever equal to the straight-line value computed for average skidding distance. Koger (1976) found that a correction factor of 1.86 was needed to adjust average skidding distance to the actual travel distance. The user can supply this correction factor (1.86) or one pertinent to area conditions through the input variable, AC (card type 13, Appendix 5). In most cases, if some correction factor is not used, skidding costs will be significantly underestimated.

Fixed Skidding Distance

In most cases an area (Figures 10-13) will not be adjacent to a landing. The distance traveled by the skidder from the landing to reach the area boundary is referred to as the fixed skidding distance. This value must be calculated or estimated by the user and coded in the input data (variabale AF, card type 13, Appendix 5).

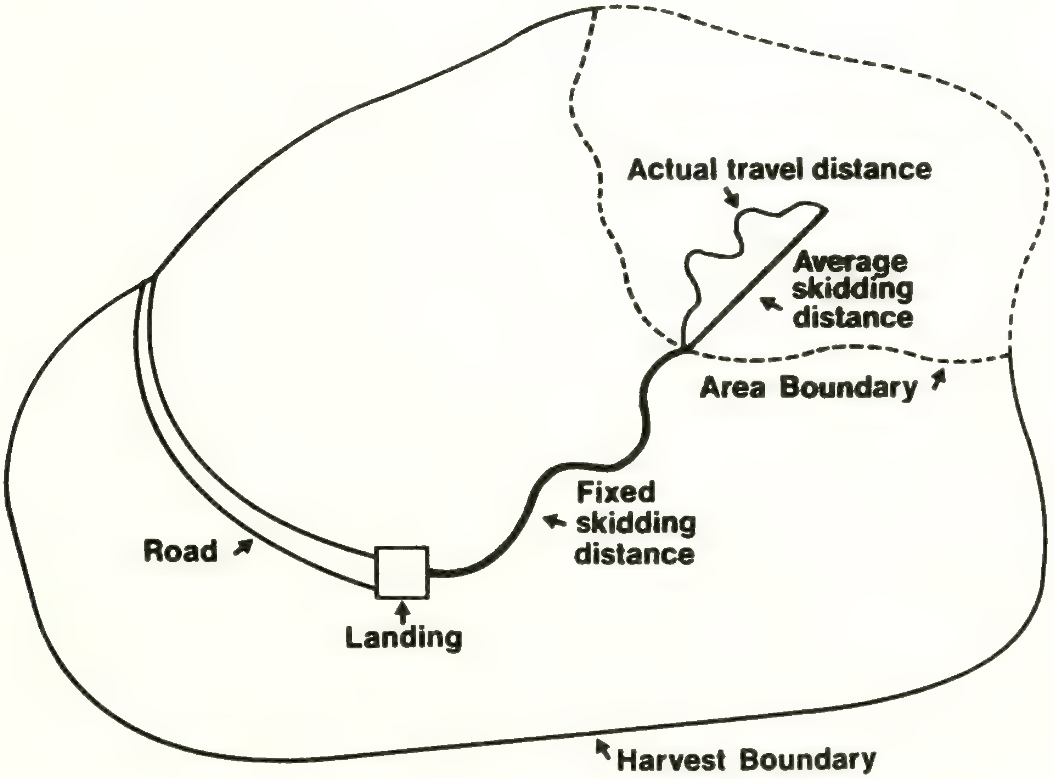
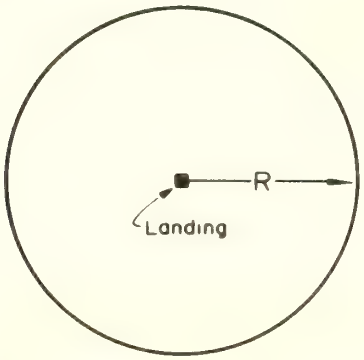


Figure I.--Relationship among average skidding distance, actual travel distance, and fixed skidding distance

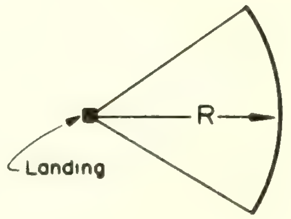
AVERAGE SKIDDING DISTANCE (ASD) FOR SIMPLE GEOMETRIC SHAPES

CIRCLE (Suddarth 1952)



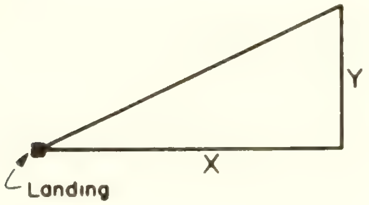
$$ASD = (2/3)R$$

CIRCULAR SEGMENT (Suddarth 1952)



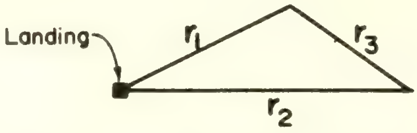
$$ASD = (2/3)R$$

RIGHT TRIANGLE (Suddarth 1952)



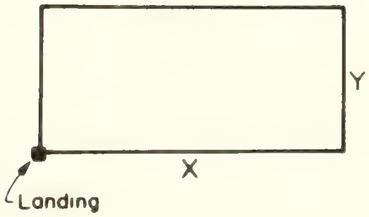
$$ASD = \sqrt{\frac{x^2+y^2}{3}} - \left[\frac{x^2}{3y}\right] \ln \left[\tan\left\{\frac{\arctan\left(\frac{x}{y}\right)}{2}\right\}\right]$$

ANY TRIANGLE (Peters 1978)



$$ASD = \frac{r_1+r_2}{6r_3^2}\left[r_3^2+(r_1-r_2)^2\right] + \frac{\left[r_3^2-(r_1-r_2)^2\right]\left[(r_1+r_2)^2-r_3^2\right]}{12r_3^3} \ln\left[\frac{r_1+r_2+r_3}{r_1+r_2-r_3}\right]$$

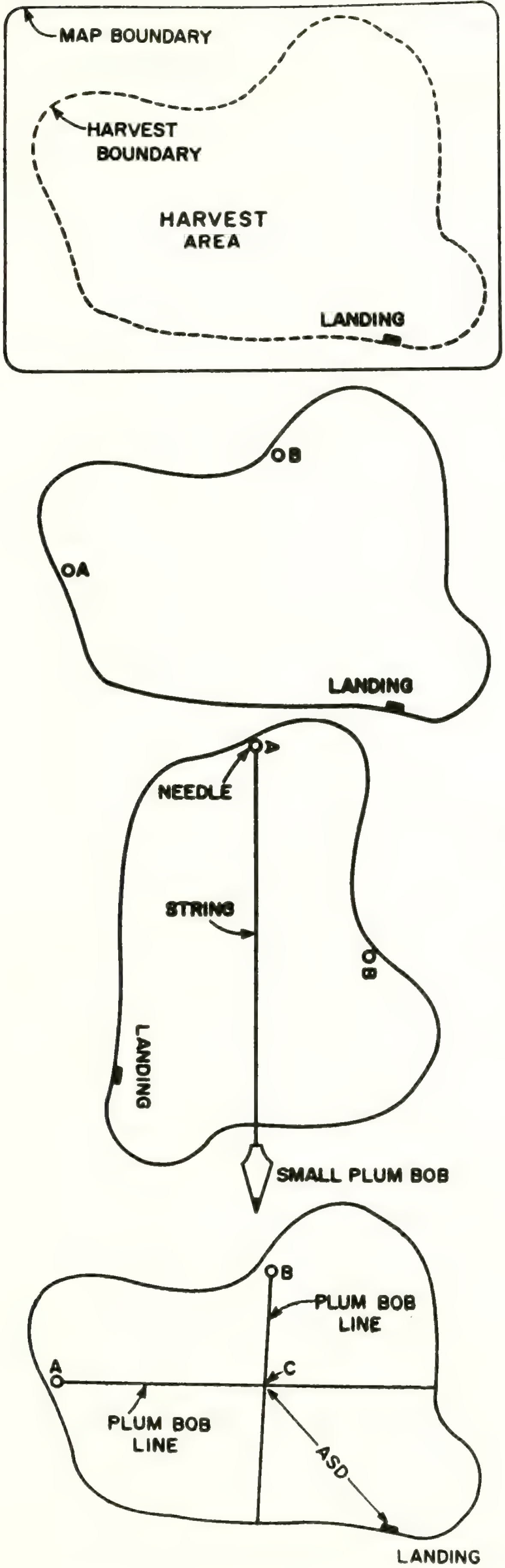
RECTANGLE (Suddarth 1952)



$$ASD = \sqrt{\frac{x^2+y^2}{3}} - \left(\left[\frac{y^2}{6x}\right] \ln \left[\tan\left\{\frac{\arctan\left(\frac{y}{x}\right)}{2}\right\}\right]\right) - \left(\left[\frac{x^2}{6y}\right] \ln \left[\tan\left\{\frac{\arctan\left(\frac{x}{y}\right)}{2}\right\}\right]\right)$$

Where ln = natural log, base e ; tan = tangent ; arctan = arctangent

Figure II.--Average skidding distance equations for areas with simple geometric shapes



STEP 1: DETERMINE HARVEST BOUNDARY AND LANDING LOCATION.

STEP 2: SEPARATE HARVEST AREA FROM MAP BY CUTTING ALONG HARVEST BOUNDARY LINE.

STEP 3: MAKE TWO SMALL HOLES NEAR MARGIN OF HARVEST BOUNDARY (A & B). SEPARATE FROM LANDING BY ABOUT 1/3 BOUNDARY CIRCUMFERENCE.

STEP 4: PLACE A NEEDLE IN HOLE AT LOCATION (A) AND MAKE SURE THAT HARVEST AREA CUTOUT ROTATES FREELY ABOUT THE NEEDLE AXIS. ATTACH A SMALL PLUM BOB TO NEEDLE AND MARK PLUM LINE ON CUTOUT. REPEAT THIS PROCESS AT LOCATION (B).

STEP 5: THE CENTROID OF THE HARVEST AREA WILL BE AT THE INTERSECTION OF THE TWO PLUM BOB LINES (C). MEASURE THE DISTANCE FROM POINT C TO THE LANDING WITH A RULER. THIS DISTANCE MULTIPLIED BY THE MAP SCALE WILL GIVE A CLOSE APPROXIMATION OF AVERAGE SKIDDING DISTANCE (ASD).

Figure III.--Graphic method for determining average skidding distance when landing is on boundary edge

Appendix 3—Harvesting Example Problem Method Assumptions

Table 5.--Harvesting equipment assumptions

Equipment Description	Equipment Efficiency Factor	Cycle Volume (1/4" Int. Bdft)	Scheduled Hourly Costs ($) +
crawler tractor (72 hp)*	0.70	NA	$21.63
rubber-tired skidder (70 hp)*	0.80	400 - 510	19.05
rubber-tired skidder (90 hp)*	0.85	420 - 550	22.30
tandem-axle truck (2 ton)	0.80	1,800	19.50
tandem-axle truck (2 ton)	0.80	2,000	20.50
knuckleboom loader*	NA	NA	13.00
repair truck*	NA	NA	8.50

+ includes $5.50 per scheduled hour for labor costs

* equipment involved in system move between landings

Table 6.--Road segment data

Road Section	Road Length (feet)	Road Width (feet)	Constructed Slope (%)	Sidehill Slope (%)	Cut Ratio (feet)	Fill Ratio (feet)	Building Difficulty
a - b	350	15	-10	10	1.5	1.5	100
b - c	450	15	-8	15	1.5	1.5	150
c - d	325	15	-10	12	1.5	1.5	100
d - e	800	15	-10	12	1.5	1.5	150
e - f	600	14	-8	10	1.5	1.5	100
f - g	700	14	-10	8	1.5	1.5	150
g - h	650	13	-15	20	1.5	1.5	100
h - i	1,250	12	-12	15	1.5	1.5	100
i - j	1,650	12	-6	10	1.5	1.5	100

Table 7.--Landing construction data

Method Number	Landing Code Letter	Distance From Harvest Boundary (feet)	Landing Size (acres)	Average Depth of Cut (feet)	Construction Difficulty Factor	Equipment System Move Time (hours)
1	A	350	1.5	0.3	1.00	0.0
2	A	350	0.6	0.3	1.00	0.0
2	B	2,525	1.5	0.4	0.90	2.0
3	A	350	0.6	0.3	1.00	0.0
3	B	2,525	0.8	0.4	0.90	2.0
3	C	3,875	1.5	0.4	1.00	1.8
4	A	350	0.6	0.3	1.00	0.0
4	B	2,525	0.8	0.4	0.90	2.0
4	C	3,875	0.9	0.4	1.00	1.8
4	D	6,775	1.2	0.3	0.80	2.2

Table 8.--Skidding data for method 1

Landing Code	Area Code	Area Volume (1/4"Int)	Area Size (acres)	Average Skidding Distance (feet)	Fixed Skidding Distance (feet)	Trail Slope (%)	Fixed Cycle Time (min)
A	1	65,000	26	485	0	5	7
A	2	70,000	28	1,005	265	-2	7
A	4	40,000	16	525	2,080	-3	7
A	5	22,500	9	415	3,700	-5	7
A	7	90,000	45	1,180	1,200	-10	9
A	8	4,000	2	275	4,000	-8	9
A	9	15,000	10	840	3,000	-10	11
A	10	12,000	8	285	4,950	-2	11
A	11	24,000	16	1,095	4,550	5	11
A	12	16,000	16	625	5,050	10	13
A	13	27,000	27	990	6,230	10	13
A	14	15,000	15	570	8,000	5	13
A	18	26,000	13	520	5,740	15	9
A	21	30,000	15	1,095	5,050	12	9
A	22	6,000	2	170	7,700	10	5
A	23	105,000	35	900	7,225	10	5

Table 9.--Skidding data for method 2

Landing Code	Area Code	Area Volume (1/4"Int)	Area Size (acres)	Average Skidding Distance (feet)	Fixed Skidding Distance (feet)	Trail Slope (%)	Fixed Cycle Time (min)
A	1	65,000	26	485	0	5	7
A	3	57,500	23	820	265	5	7
A	4	40,000	16	525	2,080	-3	7
B	5	22,500	9	415	990	10	7
B	6	12,500	5	190	600	12	7
B	7	90,000	45	630	0	-2	9
B	8	4,000	2	275	1,300	-8	9
B	9	15,000	10	445	990	-10	11
B	10	12,000	8	285	1,680	-10	11
B	11	24,000	16	1,095	1,290	-2	11
B	12	16,000	16	625	1,780	5	13
B	13	27,000	27	990	2,670	10	13
B	14	15,000	15	570	5,050	10	13
B	18	26,000	13	520	2,080	5	9
B	21	30,000	15	1,095	1,880	15	9
B	22	6,000	2	170	3,660	12	5
B	23	105,000	35	900	4,260	10	5

Table 10.--Skidding data for method 3

Landing Code	Area Code	Area Volume (1/4"Int)	Area Size (acres)	Average Skidding Distance (feet)	Fixed Skidding Distance (feet)	Trail Slope (%)	Fixed Cycle Time (min)
A	1	65,000	26	485	0	5	7
A	3	57,500	23	820	265	5	7
A	4	40,000	16	525	2,080	-3	7
B	5	22,500	9	415	990	10	7
B	6	12,500	5	190	600	12	7
B	7	90,000	45	630	0	-2	9
B	8	4,000	2	275	1,300	-8	9
B	9	15,000	10	445	990	-10	11
C	10	12,000	8	285	790	-10	11
C	11	24,000	16	1,095	0	-2	11
C	12	16,000	16	625	300	5	13
C	13	27,000	27	990	1,390	10	13
C	14	15,000	15	570	3,660	10	13
C	18	26,000	13	520	790	5	9
C	21	30,000	15	1,095	300	15	9
C	22	6,000	2	170	2,480	12	5
C	23	105,000	35	900	2,870	10	5

Table 11.--Skidding data for method 4

Landing Code	Area Code	Area Volume (1/4"Int)	Area Size (acres)	Average Skidding Distance (feet)	Fixed Skidding Distance (feet)	Trail Slope (%)	Fixed Cycle Time (min)
A	1	65,000	26	485	0	5	7
A	3	57,500	23	820	265	5	7
A	4	40,000	16	525	2,080	-3	7
B	5	22,500	9	415	990	10	7
B	6	12,500	5	190	600	12	7
B	7	90,000	45	630	0	-2	9
B	8	4,000	2	275	1,300	-8	9
B	9	15,000	10	445	990	-10	11
C	10	12,000	8	285	790	-10	11
C	11	24,000	16	1,095	0	-2	11
C	15	6,000	6	490	300	-5	13
C	19	10,000	5	270	790	-5	9
D	16	37,000	37	900	500	-4	13
D	17	15,000	15	450	0	-5	13
D	20	16,000	8	335	2,370	3	9
D	21	30,000	15	1,170	200	4	9
D	22	6,000	2	170	2,820	4	5
D	23	105,000	35	720	150	6	5

Appendix 4—Equipment Specifications

Table 12.--Equipment horsepower and weight characteristics for selected crawler tractors

Equipment Make & Model		Equipment Horsepower (net engine)	Equipment Weight (bare, pounds)
Case	350	39	5,905
	450	51	8,850
	850	72	13,000
	1450	130	23,800
Caterpillar	D3-PS	62	10,300
	D4-DD	75	13,990
	D5-DD	105	19,200
	D6-DD	140	24,000
John Deere	JD350-C	42	8,160
	JD450-C	65	11,600
	JD550	72	12,300
International	TD-7E-PS	65	10,459
	TD-8E-PS	78	13,834
	TD-15C-PS	140	24,153
Komatsu	D45A-1	90	18,340
	D53A-15	110	22,200
	D60A-6	140	28,220
Massey-Ferguson	MF300	65	14,700
	MF400	85	20,585
	MF5WB	136	25,800

Table 13.--Equipment horsepower and weight characteristics for selected rubber-tired skidders

Equipment Make & Model	Equipment Horsepower (net engine)	Equipment Weight (bare, pounds)
Athey S-97D	97	16,250
Caterpillar 518	120	20,400
528	175	28,300
Clark Ranger 664B	82	15,890
666B	112	17,855
668B	166	24,480
Franklin 531	70	12,000
132	80	17,840
170	112	18,740
185	175	24,140
International S8	86	13,100
John Deere JD440-B	70	12,250
JD540-A	94	16,150
JD640	110	19,900
JD740	145	26,700
Pettibone 100	93	14,950
Timber Jack 208D	67	12,300
225	92	12,784
Tree Farmer C5D	90	15,890
C6D	120	18,180

Appendix 5—Data Card Types

The following 17 data card types are used in L-O-S-T to describe organized input data for the harvesting methods, areas, road segments, landings, and equipment. Unless otherwise stated, all input data is to be right justified. Input variable names beginning with INTEGER letters (I,J,K,L,M, or N) do not require decimal points. Input variable names beginning with REAL letters (A-H, & O-Z) do require a decimal point in the input field location shown. Although harvest volume units of pounds, 1/4" Int. board feet, cubic feet, or cords may be used, once a unit has been selected it must be used throughout the analysis. The input data for the harvesting example shown in Appendix 6 should be used to supplement the data card type descriptions given below.

Card Type 1: (required; one card)

1 64 cc /_/_/_ _ _ _ _ _ /_/	ATITLE()	harvesting problem title

Card Type 2: (required; one card)

2 cc /_/	NMETH	number of methods analyzed (minimum of 2 and a maximum of 4)
5 cc /_/	NDZR	number of crawler tractors (1-5)
7 8 cc /_/_/	NSKD	number of rubber-tired, cable skidders (1-10)
10 11 cc /_/_/	NTRK	number of trucks (1-10)
13 cc /_/	ICTRAT	number of user supplied constraints (0-4); allows limits on number of hours permitted for harvesting functions considered
15 cc /_/	ILPANA	linear programming option code: = 0 if linear programming analysis is performed = 1 if linear programming analysis is not performed
17 cc /_/	LPCDE	= 0 if no intermediate matrices are printed; the normal case = 1 if intermediate matrices are printed; is helpful in understanding sensivity analysis

Card Type 3: (required; one card)

1 cc /_/	IUNIT	unit code for volume; = 1 for pounds = 2 for 1/4" Int. board feet = 3 for cubic feet = 4 for cords
3 12 cc /_/_/_/_/_/_/_/_/_/./	HARVOL	total volume of harvested timber in same units as coded for IUNIT
14 18 20 cc /_/_/_/_/./_/_/	PRODPC	selling or delivered price in normal selling units (ie. $/1,000 board feet)
22 26 28 cc /_/_/_/_/./_/_/	SYSMHC	hourly cost ($/hr) to move pertinent equipment to the next landing; not an hourly move-in cost
30 35 cc /_/_/_/./_/	DFTBTM	distance in miles from mill to harvest boundary or start of constructed woods roads (can be zero if analyzing trucking within harvest boundary)

Card Type 4: (required; one card for each crawler tractor building roads ; NDZR cards required; cards adjacent)

1 4 cc /_/_/_/./	DZRHP()	net horsepower of crawler tractor; (Table 12, Appendix 4)
6 9 cc /_/./_/_/	DZREF()	crawler tractor efficiency (ie. 0.80)
11 14 16 cc /_/_/_/./_/_/	DZRHC()	hourly crawler tractor and operator cost ($/hr)

Card Type 5: (required; one card for each skidder; NSKD cards required; cards adjacent)

1 4 cc /_/_/_/./	SKDHP()	net skidder horsepower; (Table 13, Appendix 4)
6 11 cc /_/_/_/_/_/./	SKDWT()	weight of unloaded skidder in pounds; (Table 13, Appendix 4)
13 16 cc /_/./_/_/	SKDEF()	skidder efficiency (ie. 0.75)

```
18    21  23 cc
/_/_/_/./_/_/              SKDHC()    hourly skidder and operator cost ($/hr)
```

Card Type 6: (required; one card for each truck; NTRK cards required; cards adjacent); note: travel speeds must be > 0.

```
 1      4 cc
/_/_/./_/                  TKTENW()   empty truck travel speed in mph over
                                      non-woods road (Table 2, Appendix 1)

 6      9 cc
/_/_/./_/                  TKTLNW()   loaded truck travel speed in mph over
                                      non-woods road (Table 2, Appendix 1)

11      14 cc
/_/_/./_/                  TKTEWD()   empty truck travel speed in mph over
                                      woods road (Table 2, Appendix 1)
16    19 cc
/_/_/./_/                  TKTLWD()   loaded truck travel speed in mph over
                                      woods road (Table 2, Appendix 1)
21    24 cc
/_/_/./_/                  TKFTPC()   fixed time per cycle in minutes; can
                                      include delays, stops for fuel, etc.

26    29 cc
/_/./_/_/                  TKEF()     truck efficiency (ie. 0.80)

31              38   40 cc
/_/_/_/_/_/_/_/./_/_/      TKVOL()    average truck volume (Tables 3 & 4,
                                      Appendix 1); same units as IUNIT in
                                      card type 3
42    45  47 cc
/_/_/_/./_/_/              TKHC()     hourly truck and operator cost ($/hr)
```

Card Type 7: (required; one card for each method; NMETH cards required; cards adjacent)

```
 1 cc
/_/                        IMETH()    method number (1-4)

   4 cc
/_/_/                      IRDSEG()   number of road segments for this method
                                      (0-20)

 7 cc
/_/                        ILANDN()   number of landings for this method
                                      (1-8)
```

Card Type 8: (required; one card for each landing for each method; cards adjacent)

```
 1 cc
/_/                        JMN        method number--not number of methods
                                      (1-4)
```

4 cc /_/	JLN	landing number--not number of landings (1-8)
7 cc /_/_/	JNA	number of areas for this landing (1-25); not area code number
10 cc /_/_/	JMAN	maximum value of any area code number for this landing; is equal to JNA only if areas are numbered consecutively

Card Type 9: (required; one card)

1 cc /_/	JMN	control card which follows the last card type 8 and must have a 0 (zero) coded in card column 1

Card Type 10: (required; one card for each road segment for each method; cards adjacent)

1 7 cc /_/_/_/_/_/_/./	ROADSL	length of road segment in feet; if there are no road segments code a 0 (zero) in card column 6 and then skip other variables on this card type
9 12 cc /_/_/./_/	ROADSW	segment road width in feet
14 18 cc /_/_/_/_/./	ROADSP	percent slope (+,-) or road segment in direction of construction
20 24 cc /_/_/_/_/./	ROADSS	percent slope (+ only) of side-hill adjacent road
26 28 30 cc /_/_/./_/_/	ROADCR	cut ratio; rise in cut per 1 foot of base (ie. 1.50)
32 34 36 cc /_/_/./_/_/	ROADFR	fill ratio; drop in fill per 1 foot of base (ie. 1.50)
38 42 cc /_/_/_/_/./	ROADTY	road construction difficulty code; = 10 for road constructed under adverse conditions or for high volume truck traffic = 500 for road constructed under average conditions = 1000 for road constructed under favorable conditions

= 2000 for road constructed under very favorable conditions, or the up-grading of an existing road
= 3000 for landing constructed under average conditions

note: intermediate values (ie. 520, 760) can be used; trial and error techniques may be required to obtain desired or expected times and costs

Card Type 11: (required; one card)

1 cc /_/	ILDZR	input order number of crawler tractor in card type 4 that will be used to construct all landings (ie. if the second crawler tractor in card type 4 is used, then code a 2 in card column 1); only one crawler tractor is permitted to construct landings

Card Type 12: (required; one card for each landing for each method; cards adjacent; input all landings for first method, then all landings for second method, etc.)

1 8 cc /_/_/_/_/_/_/_/./	DSFTB()	distance in feet this landing is from harvest boundary as measured along woods road
10 13 cc /_/_/./_/	ACRESL	landing size in acres
15 18 cc /_/_/./_/	CUTL	average depth in feet of earth removed in constructing this landing
20 23 cc /_/./_/_/	EFFL	landing construction difficulty factor; must be greater than 0.0; suggest: = less than 1.00 for difficult sites = 1.0 for average sites = greater than 1.0 for favorable sites
25 29 cc /_/_/_/./_/	SYSMHR	number of hours required to move equipment to this landing; not a move-in time, but a system move between landing time; should be 0 (zero) for the first landing

Card Type 13: (required; one card for each area for each method; cards adjacent)

1 cc /_/	IMN	method number

3 cc /_/	ILN	landing number
5 cc /_/_/	IAN	area code number
6 14 cc /_/_/_/_/_/_/_/_/./	AV	area volume in same units used for variable IUNIT in card type 3
15 20 cc /_/_/_/_/_/./	AA	area acres
21 28 cc /_/_/_/_/_/_/_/./	AN	average or minimum skidding distance in feet for this area; if AN=AX (next variable) average skidding distance option is assumed and skidding time is not based on integration (dx)
29 36 cc /_/_/_/_/_/_/_/./	AX	average or maximum skidding distance in feet for this area; if AX=AN (last variable) average skidding distance option is assumed and skidding time is not based on integration (dx)
37 44 cc /_/_/_/_/_/_/_/./	AF	fixed skidding distance in feet from landing to start of harvest area; is 0 (zero) if landing is located on edge or inside of harvest area; this is actual travel distance and not straight line distance (Figure I, Appendix 2)
46 48 50 cc /_/_/./_/_/	AC	correction factor adjusting straight line skidding distance to actual distance traveled by skidder inside an area; suggest 1.86; use 1.00 for no correction
52 56 cc /_/_/_/_/./	AS	slope of skid trail (+,-) in percent, measured in travel loaded direction
58 61 cc /_/./_/_/	AD	difficulty factor code used to provide more sensitivity for actual skidding conditions on each area; can be used to model increased skidder interactions, multiple skidders on small areas, or adverse skidding conditions; = less than 1.00 for adverse skidding conditions or high skidder interaction = 1.00 for average skidding conditions and no significant skidder interaction = greater than 1.00 for very favorable skidding conditions and no skidder interactions

63 66 cc /_/_/./_/	AT	average fixed skidding time per cycle in minutes (ie. hooking, unhooking, decking)

Card Type 14: (required; one card)

1 cc /_/	IMN	control card which follows the last card type 13; must have a 0 (zero) coded in card column 1

Card Type 15: (required; one card for each method, for each landing, for each area, for each skidder; cards adjacent)

1 cc /_/	KM	method number(1-4)
4 cc /_/	KL	landing number (1-8)
7 cc /_/_/	KA	area code number; same as IAN in card type 13
10 cc /_/_/	KS	skidder input order number; must be in same sequence as coded in card type 5.
11 20 cc /_/_/_/_/_/_/_/_/./_/	SKVMN	average or minimum volume skidded per cycle; if SKVMN=SKVMX (next variable) average skid volume is assumed and skidding time is not based on integration (dv); volume ranges (Table 1, Appendix 1); volume must be in same units as used for variable IUNIT in card type 3
21 30 cc /_/_/_/_/_/_/_/_/./_/	SKVMX	average or maximum volume skidded per cycle; if SKVMX=SKVMN (last variable) average skid volume is assumed and skidding time is not based on integration (dv); volume ranges (Table 1, Appendix 1); volume must be in same units as used for variable IUNIT in card type 3

Card Type 16: (required; one card for each landing for each method; cards adjacent)

1 cc /_/	ITMN	method number (1-4)
4 cc /_/	ITLN	landing number(1-8)

6 9 cc /_/./_/_/	TKTVCF	truck speed correction factor; reflects change in truck travel speed as a function of distance traveled over woods road; ratio of ending travel speed on woods road to beginning travel speed on woods road; a value of 1.00 would indicate the use of average travel speed

Card Type 17: (optional; use only if adding constraints for number of hours; use only if value of ICTRAT in card type 2 is greater than zero; one card required for each constraint; cards adjacent; most often used after one computer analysis has been made without upper bound constraints; upper bound values are usually not know in advance of an initial unconstrained analysis

1 cc /_/	ICSTFO	constraint code: = 1 if supplying upper bound on road construction hours = 2 if supplying upper bound on landing construction and system move hours = 3 if supplying upper bound on skiding hours = 4 if supplying upper bound on trucking hours
3 10 cc /_/_/_/_/_/_/_/./		upper bound value of constraint in hours

Appendix 6—Harvesting Example Problem Input Data

```
HYPOTHETICAL HARVESTING EXAMPLE: 4 METHODS
 4  1  2  2 2 0 1
2     567500.   95.00   50.63  30.5
 72. 0.70  21.63
 70. 14175. 0.80  19.05
 90. 16675. 0.85  22.30
34.0 28.0  8.3  5.3 15.0 0.80     1800.00  19.50
34.0 26.0  8.3  5.0 15.0 0.80     2000.00  20.50
1  1  1
2  5  2
3  7  3
4  9  4
1  1 16 23
2  1  3  4
2  2 14 23
3  1  3  4
3  2  5  9
3  3  9 23
4  1  3  4
4  2  5  9
4  3  4 19
4  4  6 23
0
   350. 15.0  -10.    10.  1.50  1.50  100.
   350. 15.0  -10.    10.  1.50  1.50  100.
   450. 15.0   -8.    15.  1.50  1.50  150.
   325. 15.0  -10.    12.  1.50  1.50  100.
   800. 15.0  -10.    12.  1.50  1.50  150.
   600. 14.0   -8.    10.  1.50  1.50  100.
   350. 15.0  -10.    10.  1.50  1.50  100.
   450. 15.0   -8.    15.  1.50  1.50  150.
   325. 15.0  -10.    12.  1.50  1.50  100.
   800. 15.0  -10.    12.  1.50  1.50  150.
   600. 14.0   -8.    10.  1.50  1.50  100.
   700. 14.0  -10.     8.  1.50  1.50  150.
   650. 13.0  -15.    20.  1.50  1.50  100.
   350. 15.0  -10.    10.  1.50  1.50  100.
   450. 15.0   -8.    15.  1.50  1.50  150.
   325. 15.0  -10.    12.  1.50  1.50  100.
   800. 15.0  -10.    12.  1.50  1.50  150.
   600. 14.0   -8.    10.  1.50  1.50  100.
   700. 14.0  -10.     8.  1.50  1.50  150.
   650. 13.0  -15.    20.  1.50  1.50  100.
  1250. 12.0  -12.    15.  1.50  1.50  100.
  1650. 12.0   -6.    10.  1.50  1.50  100.
1
    350.  1.5  0.3 1.00   0.0
    350.  0.6  0.3 1.00   0.0
   2525.  1.5  0.4 0.90   2.0
```

```
      350.  0.6  0.3 1.00   0.0
     2525.  0.8  0.4 0.90   2.0
     3875.  1.5  0.4 1.00   1.8
      350.  0.6  0.3 1.00   0.0
     2525.  0.8  0.4 0.90   2.0
     3875.  0.9  0.4 1.00   1.8
     6775.  1.2  0.3 0.80   2.2
1 1 1   65000.   26.    485.    485.       0.  1.9     5. 1.00  7.0
1 1 2   70000.   28.   1005.   1005.     265.  1.9    -2. 1.00  7.0
1 1 4   40000.   16.    525.    525.    2080.  1.9    -3. 1.00  7.0
1 1 5   22500.    9.    415.    415.    3700.  1.9    -5. 1.00  7.0
1 1 7   90000.   45.   1180.   1180.    1200.  1.4   -10. 1.00  9.0
1 1 8    4000.    2.    275.    275.    4000.  1.4    -8. 0.90  9.0
1 1 9   15000.   10.    840.    840.    3000.  1.4   -10. 1.00 11.0
1 110   12000.    8.    285.    285.    4950.  1.4    -2. 1.00 11.0
1 111   24000.   16.   1095.   1095.    4550.  1.4    +5. 0.95 11.0
1 112   16000.   16.    625.    625.    5050.  1.5   +10. 0.85 13.0
1 113   27000.   27.    990.    990.    6230.  1.5   +10. 0.90 13.0
1 114   15000.   15.    570.    570.    8000.  1.5    +5. 0.90 13.0
1 118   26000.   13.    520.    520.    5740.  1.5   +15. 0.80  9.0
1 121   30000.   15.   1095.   1095.    5050.  1.7   +12. 0.90  9.0
1 122    6000.    2.    170.    170.    7700.  1.7   +10. 1.00  5.0
1 123  105000.   35.    900.    900.    7225.  1.7   +10. 1.00  5.0
2 1 1   65000.   26.    485.    485.       0.  1.6     5. 1.00  7.0
2 1 3   57500.   23.    820.    820.     265.  1.6     5. 1.00  7.0
2 1 4   40000.   16.    525.    525.    2080.  1.6    -3. 1.00  7.0
2 2 5   22500.    9.    415.    415.     990.  1.6    10. 1.00  7.0
2 2 6   12500.    5.    190.    190.     600.  1.6    12. 1.00  7.0
2 2 7   90000.   45.    630.    630.       0.  1.6    -2. 1.00  9.0
2 2 8    4000.    2.    275.    275.    1300.  1.6    -8. 1.00  9.0
2 2 9   15000.   10.    445.    445.     990.  1.6   -10. 1.00 11.0
2 210   12000.    8.    285.    285.    1680.  1.4   -10. 1.00 11.0
2 211   24000.   16.   1095.   1095.    1290.  1.4    -2. 1.00 11.0
2 212   16000.   16.    625.    625.    1780.  1.4     5. 0.95 13.0
2 213   27000.   27.    990.    990.    2670.  1.4    10. 0.85 13.0
2 214   15000.   15.    570.    570.    5050.  1.9    10. 0.90 13.0
2 218   26000.   13.    520.    520.    2080.  1.5     5. 0.90  9.0
2 221   30000.   15.   1095.   1095.    1880.  1.5    15. 0.80  9.0
2 222    6000.    2.    170.    170.    3660.  1.5    12. 1.00  5.0
2 223  105000.   35.    900.    900.    4260.  1.5    10. 1.00  5.0
3 1 1   65000.   26.    485.    485.       0.  1.9     5. 1.00  7.0
3 1 3   57500.   23.    820.    820.     265.  1.9     5. 1.00  7.0
3 1 4   40000.   16.    525.    525.    2080.  1.9    -3. 1.00  7.0
3 2 5   22500.    9.    415.    415.     990.  1.6    10. 1.00  7.0
3 2 6   12500.    5.    190.    600.     600.  1.6    12. 1.00  7.0
3 2 7   90000.   45.    630.    630.       0.  1.6    -2. 1.00  9.0
3 2 8    4000.    2.    275.    275.    1300.  1.6    -8. 1.00  9.0
3 2 9   15000.   10.    445.    445.     990.  1.6   -10. 1.00 11.0
3 310   12000.    8.    285.    285.     790.  1.7   -10. 1.00 11.0
3 311   24000.   16.   1095.   1095.       0.  1.7    -2. 1.00 11.0
3 312   16000.   16.    625.    625.     300.  1.7     5. 0.95 13.0
3 313   27000.   27.    990.    990.    1390.  1.7    10. 0.85 13.0
3 314   15000.   15.    570.    570.    3660.  1.8    10. 0.90 13.0
3 318   26000.   13.    520.    520.     790.  1.8     5. 0.90  9.0
3 321   30000.   15.   1095.   1095.     300.  1.8    15. 0.80  9.0
3 322    6000.    2.    170.    170.    2480.  1.8    12. 1.00  5.0
3 323  105000.   35.    900.    900.    2870.  1.8    10. 1.00  5.0
```

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4 1 1    65000.   26.    485.    485.      0.  1.9     5. 1.00  7.0
4 1 3    57500.   23.    820.    820.    265.  1.9     5. 1.00  7.0
4 1 4    40000.   16.    525.    525.   2080.  1.9    -3. 1.00  7.0
4 2 5    22500.    9.    415.    415.    990.  1.6    10. 1.00  7.0
4 2 6    12500.    5.    190.    600.    600.  1.6    12. 1.00  7.0
4 2 7    90000.   45.    630.    630.      0.  1.6    -2. 1.00  9.0
4 2 8     4000.    2.    275.    275.   1300.  1.6    -8. 1.00  9.0
4 2 9    15000.   10.    445.    445.    990.  1.6   -10. 1.00 11.0
4 310    12000.    8.    285.    285.    790.  1.7   -10. 1.00 11.0
4 311    24000.   16.   1095.   1095.      0.  1.7    -2. 1.00 11.0
4 315     6000.    6.    490.    490.    300.  1.7    -5. 0.95 13.0
4 319    10000.    5.    270.    270.    790.  1.7    -5. 0.90  9.0
4 416    37000.   37.    900.    900.    500.  1.5    -4. 0.90 13.0
4 417    15000.   15.    450.    450.      0.  1.5    -5. 0.90 13.0
4 420    16000.    8.    335.    335.   2370.  1.5     3. 0.80  9.0
4 421    30000.   15.   1170.   1170.    200.  1.5     4. 0.80  9.0
4 422     6000.    2.    170.    170.   2820.  1.5     4. 1.00  5.0
4 423   105000.   35.    720.    720.    150.  1.5     6. 1.00  5.0
0
1  1  1  1     400.      400.
1  1  1  2     460.      460.
1  1  2  1     450.      450.
1  1  2  2     470.      470.
1  1  4  1     450.      450.
1  1  4  2     470.      470.
1  1  5  1     450.      450.
1  1  5  2     470.      470.
1  1  7  1     460.      460.
1  1  7  2     500.      500.
1  1  8  1     400.      400.
1  1  8  2     420.      420.
1  1  9  1     510.      510.
1  1  9  2     550.      550.
1  1 10  1     460.      460.
1  1 10  2     490.      490.
1  1 11  1     500.      500.
1  1 11  2     520.      520.
1  1 12  1     450.      450.
1  1 12  2     490.      490.
1  1 13  1     450.      450.
1  1 13  2     490.      490.
1  1 14  1     450.      450.
1  1 14  2     490.      490.
1  1 18  1     450.      450.
1  1 18  2     490.      490.
1  1 21  1     450.      450.
1  1 21  2     490.      490.
1  1 22  1     450.      450.
1  1 22  2     490.      490.
1  1 23  1     450.      450.
1  1 23  2     490.      490.
2  1  1  1     400.      400.
2  1  1  2     460.      460.
2  1  3  1     450.      450.
2  1  3  2     470.      470.
2  1  4  1     450.      450.
2  1  4  2     470.      470.
```

```
2  2  5  1     400.      400.
2  2  5  2     420.      420.
2  2  6  1     400.      400.
2  2  6  2     420.      420.
2  2  7  1     460.      460.
2  2  7  2     500.      500.
2  2  8  1     400.      400.
2  2  8  2     420.      420.
2  2  9  1     510.      510.
2  2  9  2     550.      550.
2  2 10  1     460.      460.
2  2 10  2     490.      490.
2  2 11  1     500.      500.
2  2 11  2     520.      520.
2  2 12  1     450.      450.
2  2 12  2     490.      490.
2  2 13  1     450.      450.
2  2 13  2     490.      490.
2  2 14  1     450.      450.
2  2 14  2     490.      490.
2  2 18  1     450.      450.
2  2 18  2     490.      490.
2  2 21  1     450.      450.
2  2 21  2     490.      490.
2  2 22  1     450.      450.
2  2 22  2     490.      490.
2  2 23  1     450.      450.
2  2 23  2     450.      450.
3  1  1  1     400.      400.
3  1  1  2     460.      460.
3  1  3  1     450.      450.
3  1  3  2     470.      470.
3  1  4  1     450.      450.
3  1  4  2     470.      470.
3  2  5  1     400.      400.
3  2  5  2     420.      420.
3  2  6  1     400.      400.
3  2  6  2     420.      420.
3  2  7  1     460.      460.
3  2  7  2     500.      500.
3  2  8  1     400.      400.
3  2  8  2     420.      420.
3  2  9  1     510.      510.
3  2  9  2     550.      550.
3  3 10  1     460.      460.
3  3 10  2     490.      490.
3  3 11  1     500.      500.
3  3 11  2     520.      520.
3  3 12  1     450.      450.
3  3 12  2     490.      490.
3  3 13  1     450.      450.
3  3 13  2     490.      490.
3  3 14  1     450.      450.
3  3 14  2     490.      490.
3  3 18  1     450.      450.
3  3 18  2     490.      490.
3  3 21  1     450.      450.
```

```
3  3 21  2     490.      490.
3  3 22  1     450.      450.
3  3 22  2     490.      490.
3  3 23  1     450.      450.
3  3 23  2     450.      450.
4  1  1  1     400.      400.
4  1  1  2     460.      460.
4  1  3  1     450.      450.
4  1  3  2     470.      470.
4  1  4  1     450.      450.
4  1  4  2     470.      470.
4  2  5  1     400.      400.
4  2  5  2     420.      420.
4  2  6  1     400.      400.
4  2  6  2     420.      420.
4  2  7  1     460.      460.
4  2  7  2     500.      500.
4  2  8  1     400.      400.
4  2  8  2     420.      420.
4  2  9  1     510.      510.
4  2  9  2     550.      550.
4  3 10  1     460.      460.
4  3 10  2     490.      490.
4  3 11  1     500.      500.
4  3 11  2     520.      520.
4  3 15  1     450.      450.
4  3 15  2     490.      490.
4  3 19  1     420.      420.
4  3 19  2     470.      470.
4  4 16  1     430.      430.
4  4 16  2     460.      460.
4  4 17  1     440.      440.
4  4 17  2     480.      480.
4  4 20  1     450.      450.
4  4 20  2     490.      490.
4  4 21  1     490.      490.
4  4 21  2     520.      520.
4  4 22  1     450.      450.
4  4 22  2     500.      500.
4  4 23  1     470.      470.
4  4 23  2     510.      510.
1  1 0.95
2  1 0.95
2  2 0.90
3  1 0.95
3  2 0.90
3  3 0.85
4  1 0.95
4  2 0.90
4  3 0.85
4  4 0.80
1     120.0
3     600.0
//
```

Appendix 7—Harvesting Example Problem Output Data

```
 TITLE L-O-S-T  RUN=    HYPOTHETICAL HARVESTING EXAMPLE: 4 METHODS
  NUMBER OF METHODS=    4
   NUMBER OF DOZERS=    1
 NUMBER OF SKIDDERS=    2
   NUMBER OF TRUCKS=    2
   LP ANALYSIS CODE=    0
     LP OUTPUT CODE=    0
 # USER CONSTRAINTS=    2
 HARVEST VOLUME=                          567500.  INT. BOARD FEET
 PRICE IN SELLING UNITS ($)=                  95.00
 HOURLY LANDING MOVE COST ($)=                50.63
 DISTANCE FROM WOODS EDGE TO MILL (MILES)=    30.5

 *****************************
 DOZER  DOZER   DOZER   HOURLY
NUMBER     HP   EFFIC     COST

     1    72.    0.70    21.63

 *****************************
                         21.63



 ***************************************************
                                              SKIDDER
 SKIDDER        SKIDDER   SKIDDER  SKIDDER     HOURLY
  NUMBER     HORSEPOWER    WEIGHT    EFFIC       COST

       1            70.    14175.     0.80      19.05
       2            90.    16675.     0.85      22.30

 ***************************************************
                                                41.35



******************************************************************************
         ** NON-WOODS **    ***** WOODS ****
         TRAVEL   TRAVEL    TRAVEL    TRAVEL   FIXED
          EMPTY   LOADED     EMPTY    LOADED    TIME                 CYCLE    TRUCK
 TRUCK    SPEED    SPEED     SPEED     SPEED     PER   TRUCK       TRUCK   HOURLY
NUMBER      MPH      MPH       MPH       MPH    LOAD   EFFIC      VOLUME     COST

    1     34.00    28.00      8.30      5.30   15.00    0.80     1800.00    19.50
    2     34.00    26.00      8.30      5.00   15.00    0.80     2000.00    20.50

******************************************************************************
                                                                            40.00
```

```
***************************
         NUMBER    NUMBER
METHOD    ROAD        OF
NUMBER  SEGMENTS  LANDINGS

     1         1         1
     2         5         2
     3         7         3
     4         9         4

***************************
```

```
*******************************************
                    NUMBER
METHOD   LANDING        OF      MAXIMUM AREA
NUMBER    NUMBER     AREAS      CODE  NUMBER

     1         1        16                23
     2         1         3                 4
     2         2        14                23
     3         1         3                 4
     3         2         5                 9
     3         3         9                23
     4         1         3                 4
     4         2         5                 9
     4         3         4                19
     4         4         5                23

*******************************************
```

```
************************************************************************************************************************
                                                            CUT     FILL     ROAD
METHOD  SEGMENT   DOZER     ROAD    ROAD    ROAD    SIDE   SLOPE    SLOPE    TYPE     CUBIC     ACRES  SEGMENT  SEGMENT  METHOD  METHOD
NUMBER   NUMBER  NUMBER   LENGTH   WIDTH   SLOPE   SLOPE   RATIO    RATIO    CODE     YARDS   CLEARED    HOURS     COST   HOURS    COST

     1        1       1     350.    15.0    -10.     10.    1.50     1.50    100.      46.9       0.1      7.9   170.07
     1                      350.                                                     46.9       0.1                         7.9    170.

     2        1       1     350.    15.0    -10.     10.    1.50     1.50    100.      46.9       0.1      7.9   170.07
     2        2       1     450.    15.0     -8.     15.    1.50     1.50    150.      99.2       0.2      7.8   169.00
     2        3       1     325.    15.0    -10.     12.    1.50     1.50    100.      54.2       0.1      7.7   167.38
     2        4       1     800.    15.0    -10.     12.    1.50     1.50    150.     133.3       0.3     12.7   274.67
     2        5       1     600.    14.0     -8.     10.    1.50     1.50    100.      70.0       0.2     13.0   280.23
     2                     2525.                                                    403.6       1.0                        49.1   1061.

     3        1       1     350.    15.0    -10.     10.    1.50     1.50    100.      46.9       0.1      7.9   170.07
     3        2       1     450.    15.0     -8.     15.    1.50     1.50    150.      99.2       0.2      7.8   169.00
     3        3       1     325.    15.0    -10.     12.    1.50     1.50    100.      54.2       0.1      7.7   167.38
     3        4       1     800.    15.0    -10.     12.    1.50     1.50    150.     133.3       0.3     12.7   274.67
     3        5       1     600.    14.0     -8.     10.    1.50     1.50    100.      70.0       0.2     13.0   280.23
     3        6       1     700.    14.0    -10.      8.    1.50     1.50    150.      63.1       0.3      9.4   202.75
     3        7       1     650.    13.0    -15.     20.    1.50     1.50    100.     158.8       0.3     16.7   360.69
     3                     3875.                                                    625.5       1.6                        75.1   1625.

     4        1       1     350.    15.0    -10.     10.    1.50     1.50    100.      46.9       0.1      7.9   170.07
     4        2       1     450.    15.0     -8.     15.    1.50     1.50    150.      99.2       0.2      7.8   169.00
     4        3       1     325.    15.0    -10.     12.    1.50     1.50    100.      54.2       0.1      7.7   167.38
     4        4       1     800.    15.0    -10.     12.    1.50     1.50    150.     133.3       0.3     12.7   274.67
     4        5       1     600.    14.0     -8.     10.    1.50     1.50    100.      70.0       0.2     13.0   280.23
     4        6       1     700.    14.0    -10.      8.    1.50     1.50    150.      63.1       0.3      9.4   202.75
     4        7       1     650.    13.0    -15.     20.    1.50     1.50    100.     158.8       0.3     16.7   360.69
     4        8       1    1250.    12.0    -12.     15.    1.50     1.50    100.     176.3       0.4     27.1   587.16
     4        9       1    1650.    12.0     -6.     10.    1.50     1.50    100.     141.5       0.5     32.3   698.43
     4                     6775.                                                    943.3       2.6                       134.6   2910.

************************************************************************************************************************
```

METHOD NUMBER	LANDING NUMBER	DISTANCE FROM BOUNDARY	LANDING SIZE ACRES	AVERAGE CUT DEPTH	DOZER HP	HOURLY DOZER COST	EFFIC CODE	LANDING BUILDING HOURS	LANDING BUILDING COST	SYSTEM MOVE HOURS	SYSTEM MOVE COST	WEIGHTED BUILDING & MOVING HOURS	METHOD MOVE & LANDING COST
1	1	350.	1.5	0.3	72.	21.63	1.00	2.60	56.27	0.0	0.00		
1												0.78	56.27
2	1	350.	0.6	0.3	72.	21.63	1.00	1.04	22.51	0.0	0.00		
2	2	2525.	1.5	0.4	72.	21.63	0.90	3.10	67.13	2.0	101.26		
2												2.64	190.90
3	1	350.	0.6	0.3	72.	21.63	1.00	1.04	22.51	0.0	0.00		
3	2	2525.	0.9	0.4	72.	21.63	0.90	1.66	35.80	2.0	101.26		
3	3	3875.	1.5	0.4	72.	21.63	1.00	2.79	60.42	1.8	91.13		
3												4.31	311.13
4	1	350.	0.6	0.3	72.	21.63	1.00	1.04	22.51	0.0	0.00		
4	2	2525.	0.9	0.4	72.	21.63	0.90	1.66	35.80	2.0	101.26		
4	3	3875.	0.9	0.4	72.	21.63	1.00	1.68	36.25	1.8	91.13		
4	4	5775.	1.2	0.3	72.	21.63	0.80	2.60	56.27	2.2	111.39		
4												6.29	454.62

METHOD NUMBER	LANDING NUMBER	AREA NUMBER	AREA VOLUME	AREA ACRES	MINIMUM SKIDDING DISTANCE	MAXIMUM SKIDDING DISTANCE	FIXED SKIDDING DISTANCE	SKIDDING CORRECTION FACTOR	TRAIL TRAVEL DIRECTION	SLOPE LOADED (%)	AREA DIFFICULTY FACTOR	FIXED TIME CYCLE
1	1	1	65000.	26.	485.	485.	0.	1.90		5.	1.00	7.0
1	1	2	70000.	28.	1005.	1005.	265.	1.90		-2.	1.00	7.0
1	1	4	40000.	16.	525.	525.	2080.	1.90		-3.	1.00	7.0
1	1	5	22500.	9.	415.	415.	3700.	1.90		-5.	1.00	7.0
1	1	7	90000.	45.	1180.	1180.	1200.	1.40		-10.	1.00	9.0
1	1	8	4000.	2.	275.	275.	4000.	1.40		-8.	0.90	9.0
1	1	9	15000.	10.	840.	840.	3000.	1.40		-10.	1.00	11.0
1	1	10	12000.	8.	285.	285.	4950.	1.40		-2.	1.00	11.0
1	1	11	24000.	16.	1095.	1095.	4550.	1.40		5.	0.90	11.0
1	1	12	16000.	16.	625.	625.	5050.	1.50		10.	0.80	13.0
1	1	13	27000.	27.	590.	590.	6230.	1.50		10.	0.90	13.0
1	1	14	15000.	15.	570.	570.	8000.	1.50		5.	0.90	13.0
1	1	18	26000.	13.	520.	520.	5740.	1.50		15.	0.80	9.0
1	1	21	30000.	15.	1095.	1095.	5050.	1.70		12.	0.90	9.0
1	1	22	6000.	2.	170.	170.	7700.	1.70		10.	1.00	5.0
1	1	23	105000.	35.	500.	900.	7225.	1.70		10.	1.00	5.0
2	1	1	65000.	26.	485.	485.	0.	1.60		5.	1.00	7.0
2	1	3	57500.	23.	820.	820.	265.	1.60		5.	1.00	7.0
2	1	4	40000.	16.	525.	525.	2080.	1.60		-3.	1.00	7.0
2	2	5	22500.	9.	415.	415.	990.	1.60		10.	1.00	7.0
2	2	6	12500.	5.	190.	190.	600.	1.60		12.	1.00	7.0
2	2	7	90000.	45.	630.	630.	0.	1.60		-2.	1.00	9.0
2	2	8	4000.	2.	275.	275.	1300.	1.60		-8.	1.00	9.0
2	2	9	15000.	10.	445.	445.	990.	1.60		-10.	1.00	11.0
2	2	10	12000.	8.	285.	285.	1680.	1.40		-10.	1.00	11.0
2	2	11	24000.	16.	1095.	1095.	1290.	1.40		-2.	1.00	11.0
2	2	12	16000.	16.	625.	625.	1780.	1.40		5.	0.90	13.0
2	2	13	27000.	27.	590.	990.	2670.	1.40		10.	0.80	13.0
2	2	14	15000.	15.	570.	570.	5050.	1.90		10.	0.90	13.0
2	2	18	26000.	13.	520.	520.	2080.	1.50		5.	0.90	9.0
2	2	21	30000.	15.	1095.	1095.	1880.	1.50		15.	0.80	9.0
2	2	22	6000.	2.	170.	170.	3660.	1.50		12.	1.00	5.0
2	2	23	105000.	35.	900.	900.	4260.	1.50		10.	1.00	5.0
3	1	1	65000.	26.	485.	485.	0.	1.90		5.	1.00	7.0
3	1	3	57500.	23.	820.	820.	265.	1.90		5.	1.00	7.0
3	1	4	40000.	16.	525.	525.	2080.	1.90		-3.	1.00	7.0
3	2	5	22500.	9.	415.	415.	990.	1.60		10.	1.00	7.0
3	2	6	12500.	5.	190.	600.	600.	1.60		12.	1.00	7.0
3	2	7	90000.	45.	630.	630.	0.	1.60		-2.	1.00	9.0
3	2	8	4000.	2.	275.	275.	1300.	1.60		-8.	1.00	9.0
3	2	9	15000.	10.	445.	445.	990.	1.60		-10.	1.00	11.0
3	3	10	12000.	8.	285.	285.	750.	1.70		-10.	1.00	11.0
3	3	11	24000.	16.	1095.	1055.	0.	1.70		-2.	1.00	11.0
3	3	12	16000.	16.	625.	625.	300.	1.70		5.	0.90	13.0
3	3	13	27000.	27.	590.	590.	1390.	1.70		10.	0.80	13.0
3	3	14	15000.	15.	570.	570.	3660.	1.80		10.	0.90	13.0
3	3	18	26000.	13.	520.	520.	790.	1.80		5.	0.90	9.0
3	3	21	30000.	15.	1095.	1095.	300.	1.80		15.	0.80	9.0
3	3	22	6000.	2.	170.	170.	2480.	1.80		12.	1.00	5.0
3	3	23	105000.	35.	900.	900.	2870.	1.80		10.	1.00	5.0
4	1	1	65000.	26.	485.	485.	0.	1.90		5.	1.00	7.0
4	1	3	57500.	23.	820.	820.	265.	1.90		5.	1.00	7.0
4	1	4	40000.	16.	525.	525.	2080.	1.90		-3.	1.00	7.0
4	2	5	22500.	9.	415.	415.	990.	1.60		10.	1.00	7.0
4	2	6	12500.	5.	190.	600.	600.	1.60		12.	1.00	7.0
4	2	7	90000.	45.	630.	630.	0.	1.60		-2.	1.00	9.0
4	2	8	4000.	2.	275.	275.	1300.	1.60		-8.	1.00	9.0
4	2	9	15000.	10.	445.	445.	990.	1.60		-10.	1.00	11.0
4	3	10	12000.	8.	285.	285.	750.	1.70		-10.	1.00	11.0
4	3	11	24000.	16.	1095.	1055.	0.	1.70		-2.	1.00	11.0
4	3	15	6000.	6.	490.	490.	300.	1.70		-5.	0.90	13.0
4	3	19	10000.	5.	270.	270.	790.	1.70		-5.	0.90	9.0
4	4	16	37000.	37.	500.	500.	500.	1.50		-4.	0.90	13.0
4	4	17	15000.	15.	450.	450.	0.	1.50		-5.	0.90	13.0
4	4	20	16000.	8.	335.	335.	2370.	1.50		3.	0.80	9.0
4	4	21	30000.	15.	1170.	1170.	200.	1.50		4.	0.80	9.0
4	4	22	6000.	2.	170.	170.	2820.	1.50		4.	1.00	5.0
4	4	23	105000.	35.	720.	720.	150.	1.50		6.	1.00	5.0

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*****************************************************************************************************************************************
                                                                                 *********** ALL SKIDDERS WORKING TOGETHER ***********
                                                                        AREA
                                MINIMUM    MAXIMUM     CYCLE  NUMBER    SKID
METHOD  LAND   AREA   SKID     VOLUME     VOLUME      TIME      OF     TIME         AREA    LANDING    LANDING      METHOD      METHOD
    NO    NO     NO     NO   SKIDDED    SKIDDED   MINUTES   CYCLES    HOURS     SKIDDING   SKIDDING   SKIDDING    SKIDDING    SKIDDING
                                                                                    HOURS      HOURS      COSTS       HOURS       COSTS

     1     1      1      1     400.0      400.0     18.91     163.     51.21
     1     1      1      2     460.0      460.0     16.51     141.     38.89
     1     1      1                                                                 22.10
     1     1      2      1     450.0      450.0     32.45     156.     84.13
     1     1      2      2     470.0      470.0     27.21     149.     67.54
     1     1      2                                                                 37.46
     1     1      4      1     450.0      450.0     42.81      89.     63.42
     1     1      4      2     470.0      470.0     35.43      85.     50.25
     1     1      4                                                                 28.04
     1     1      5      1     450.0      450.0     58.71      50.     48.93
     1     1      5      2     470.0      470.0     47.97      48.     38.27
     1     1      5                                                                 21.47
     1     1      7      1     460.0      460.0     40.05     196.    130.59
     1     1      7      2     500.0      500.0     33.49     180.    100.48
     1     1      7                                                                 56.79
     1     1      8      1     400.0      400.0     64.21      10.     10.70
     1     1      8      2     420.0      420.0     52.82      10.      8.38
     1     1      8                                                                  4.70
     1     1      9      1     510.0      510.0     57.60      29.     28.23
     1     1      9      2     550.0      550.0     47.71      27.     21.69
     1     1      9                                                                 12.27
     1     1     10      1     460.0      460.0     76.48      26.     33.25
     1     1     10      2     490.0      490.0     62.93      24.     25.71
     1     1     10                                                                 14.50
     1     1     11      1     500.0      500.0    102.74      48.     82.19
     1     1     11      2     520.0      520.0     84.38      46.     64.91
     1     1     11                                                                 36.27
     1     1     12      1     450.0      450.0    121.88      36.     72.23
     1     1     12      2     490.0      490.0    101.06      33.     55.00
     1     1     12                                                                 31.22
     1     1     13      1     450.0      450.0    136.69      60.    136.69
     1     1     13      2     490.0      490.0    112.57      55.    103.38
     1     1     13                                                                 58.86
     1     1     14      1     450.0      450.0    148.22      33.     82.34
     1     1     14      2     490.0      490.0    121.35      31.     61.91
     1     1     14                                                                 35.34
     1     1     18      1     450.0      450.0    131.56      58.    126.69
     1     1     18      2     490.0      490.0    108.37      53.     95.84
     1     1     18                                                                 54.56
     1     1     21      1     450.0      450.0    120.20      67.    133.56
     1     1     21      2     490.0      490.0     98.73      61.    100.75
     1     1     21                                                                 57.43
     1     1     22      1     450.0      450.0    117.11      13.     26.03
     1     1     22      2     490.0      490.0     95.19      12.     19.43
     1     1     22                                                                 11.12
     1     1     23      1     450.0      450.0    128.61     233.    500.16
     1     1     23      2     490.0      490.0    104.40     214.    372.85
     1     1     23                                                                213.61
     1     1                                                                               695.75   28769.13
     1                                                                                                             695.75    28769.13

*****************************************************************************************************************************************
                                                                                 *********** ALL SKIDDERS WORKING TOGETHER ***********
                                                                        AREA
                                MINIMUM    MAXIMUM     CYCLE  NUMBER    SKID
METHOD  LAND   AREA   SKID     VOLUME     VOLUME      TIME      OF     TIME         AREA    LANDING    LANDING      METHOD      METHOD
    NO    NO     NO     NO   SKIDDED    SKIDDED   MINUTES   CYCLES    HOURS     SKIDDING   SKIDDING   SKIDDING    SKIDDING    SKIDDING
                                                                                    HOURS      HOURS      COSTS       HOURS       COSTS

     2     1      1      1     400.0      400.0     17.19     163.     46.57
     2     1      1      2     460.0      460.0     15.12     141.     35.62
     2     1      1                                                                 20.18
     2     1      3      1     450.0      450.0     27.00     128.     57.49
     2     1      3      2     470.0      470.0     22.96     122.     46.82
     2     1      3                                                                 25.80
     2     1      4      1     450.0      450.0     40.93      89.     60.64
     2     1      4      2     470.0      470.0     33.93      85.     48.13
     2     1      4                                                                 26.83
     2     1                                                                                72.82    3011.06
     2     2      5      1     400.0      400.0     28.95      56.     27.14
     2     2      5      2     420.0      420.0     24.62      54.     21.99
     2     2      5                                                                 12.15
     2     2      6      1     400.0      400.0     19.55      31.     10.18
     2     2      6      2     420.0      420.0     17.05      30.      8.46
     2     2      6                                                                  4.62
     2     2      7      1     460.0      460.0     21.61     196.     70.47
     2     2      7      2     500.0      500.0     18.94     180.     56.82
     2     2      7                                                                 31.46
     2     2      8      1     400.0      400.0     28.39      10.      4.73
     2     2      8      2     420.0      420.0     24.26      10.      3.95
     2     2      8                                                                  2.12
     2     2      9      1     510.0      510.0     30.36      29.     14.88
     2     2      9      2     550.0      550.0     26.17      27.     11.69
     2     2      9                                                                  6.61
     2     2     10      1     460.0      460.0     34.21      26.     14.87
     2     2     10      2     490.0      490.0     29.22      24.     11.93
     2     2     10                                                                  6.62
     2     2     11      1     500.0      500.0     45.40      48.     36.22
     2     2     11      2     520.0      520.0     38.22      46.     29.40
     2     2     11                                                                 16.25
     2     2     12      1     450.0      450.0     53.58      36.     31.75
     2     2     12      2     490.0      490.0     45.66      33.     24.85
     2     2     12                                                                 13.94
     2     2     13      1     450.0      450.0     87.09      60.     87.09
     2     2     13      2     490.0      490.0     73.10      55.     67.14
     2     2     13                                                                 37.91
     2     2     14      1     450.0      450.0    110.70      33.     61.50
     2     2     14      2     490.0      490.0     91.73      31.     46.60
     2     2     14                                                                 26.58
     2     2     18      1     450.0      450.0     50.98      58.     49.10
     2     2     18      2     490.0      490.0     42.81      53.     37.96
     2     2     18                                                                 21.37
     2     2     21      1     450.0      450.0     74.66      67.     82.96
     2     2     21      2     490.0      490.0     62.47      61.     63.74
     2     2     21                                                                 36.05
     2     2     22      1     450.0      450.0     58.82      13.     13.07
     2     2     22      2     490.0      490.0     48.47      12.      9.89
     2     2     22                                                                  5.63
     2     2     23      1     450.0      450.0     82.00     233.    318.99
     2     2     23      2     450.0      450.0     66.70     233.    259.37
     2     2     23                                                                143.03
     2     2                                                                               364.33   15065.10
     2                                                                                                             437.15    18076.16
     3     1      1      1     400.0      400.0     18.91     163.     51.21
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*****************************************************************************************************************************
                                                                                  *********** ALL SKIDDERS WORKING TOGETHER ***********
                              MINIMUM   MAXIMUM    CYCLE  NUMBER  AREASKID        AREA   LANDING   LANDING     METHOD      METHOD
METHOD  LAND  AREA  SKID   VOLUME    VOLUME     TIME      OF      TIME      SKIDDING  SKIDDING  SKIDDING   SKIDDING    SKIDDING
    NO    NO    NO    NO  SKIDDED   SKIDDED  MINUTES  CYCLES     HOURS       HOURS     HOURS     COSTS      HOURS       COSTS

     3     1     1                                                             22.10
     3     1     3     1    450.0     450.0    30.08    128.     64.05
     3     1     3     2    470.0     470.0    25.44    122.     51.86
     3     1     3                                                             28.66
     3     1     4     1    450.0     450.0    42.81     89.     63.42
     3     1     4     2    470.0     470.0    35.43     85.     50.25
     3     1     4                                                             28.04
     3     1                                                                            78.80   3258.22
     3     2     5     1    400.0     400.0    28.55     56.     27.14
     3     2     5     2    420.0     420.0    24.62     54.     21.99
     3     2     5                                                             12.15
     3     2     6     1    400.0     400.0    23.09     31.     12.03
     3     2     6     2    420.0     420.0    19.96     30.      9.90
     3     2     6                                                              5.43
     3     2     7     1    460.0     460.0    21.61    196.     70.47
     3     2     7     2    500.0     500.0    18.54    180.     56.82
     3     2     7                                                             31.46
     3     2     8     1    400.0     400.0    28.39     10.      4.73
     3     2     8     2    420.0     420.0    24.26     10.      3.85
     3     2     8                                                              2.12
     3     2     9     1    510.0     510.0    30.36     29.     14.88
     3     2     9     2    550.0     550.0    26.17     27.     11.39
     3     2     9                                                              6.61
     3     2                                                                            57.77   2388.61
     3     3    10     1    460.0     460.0    25.81     26.     11.22
     3     3    10     2    490.0     490.0    22.56     24.      9.21
     3     3    10                                                              5.06
     3     3    11     1    500.0     500.0    33.94     48.     27.15
     3     3    11     2    520.0     520.0    29.11     46.     22.39
     3     3    11                                                             12.27
     3     3    12     1    450.0     450.0    35.33     36.     20.96
     3     3    12     2    490.0     490.0    31.02     33.     16.88
     3     3    12                                                              9.35
     3     3    13     1    450.0     450.0    69.85     60.     65.85
     3     3    13     2    490.0     490.0    59.23     55.     54.39
     3     3    13                                                             30.58
     3     3    14     1    450.0     450.0    87.39     33.     48.55
     3     3    14     2    490.0     490.0    73.01     31.     37.25
     3     3    14                                                             21.08
     3     3    18     1    450.0     450.0    34.84     58.     33.55
     3     3    18     2    490.0     490.0    29.83     53.     26.38
     3     3    18                                                             14.77
     3     3    21     1    450.0     450.0    51.88     67.     57.64
     3     3    21     2    490.0     490.0    44.03     61.     44.93
     3     3    21                                                             25.25
     3     3    22     1    450.0     450.0    42.71     13.      9.49
     3     3    22     2    490.0     490.0    35.47     12.      7.24
     3     3    22                                                              4.11
     3     3    23     1    450.0     450.0    65.85    233.    256.08
     3     3    23     2    450.0     450.0    53.79    233.    209.18
     3     3    23                                                            115.13
     3     3                                                                           237.59   5824.48
     3                                                                                                       374.16    15471.31
     4     1     1     1    400.0     400.0    18.51    163.     51.21
     4     1     1     2    460.0     460.0    16.51    141.     38.89
     4     1     1                                                             22.10
     4     1     3     1    450.0     450.0    30.08    128.     64.05
*****************************************************************************************************************************
                                                                                  *********** ALL SKIDDERS WORKING TOGETHER ***********
                              MINIMUM   MAXIMUM    CYCLE  NUMBER  AREASKID        AREA   LANDING   LANDING     METHOD      METHOD
METHOD  LAND  AREA  SKID   VOLUME    VOLUME     TIME      OF      TIME      SKIDDING  SKIDDING  SKIDDING   SKIDDING    SKIDDING
    NO    NO    NO    NO  SKIDDED   SKIDDED  MINUTES  CYCLES     HOURS       HOURS     HOURS     COSTS      HOURS       COSTS

     4     1     3     2    470.0     470.0    25.44    122.     51.86
     4     1     3                                                             28.66
     4     1     4     1    450.0     450.0    42.81     89.     63.42
     4     1     4     2    470.0     470.0    35.43     85.     50.25
     4     1     4                                                             28.04
     4     1                                                                            78.80   3258.22
     4     2     5     1    400.0     400.0    28.55     56.     27.14
     4     2     5     2    420.0     420.0    24.62     54.     21.99
     4     2     5                                                             12.15
     4     2     6     1    400.0     400.0    23.09     31.     12.03
     4     2     6     2    420.0     420.0    19.96     30.      9.90
     4     2     6                                                              5.43
     4     2     7     1    460.0     460.0    21.61    196.     70.47
     4     2     7     2    500.0     500.0    18.54    180.     56.82
     4     2     7                                                             31.46
     4     2     8     1    400.0     400.0    28.39     10.      4.73
     4     2     8     2    420.0     420.0    24.26     10.      3.85
     4     2     8                                                              2.12
     4     2     9     1    510.0     510.0    30.36     29.     14.88
     4     2     9     2    550.0     550.0    26.17     27.     11.39
     4     2     9                                                              6.61
     4     2                                                                            57.77   2388.61
     4     3    10     1    460.0     460.0    25.81     26.     11.22
     4     3    10     2    490.0     490.0    22.56     24.      9.21
     4     3    10                                                              5.06
     4     3    11     1    500.0     500.0    33.94     48.     27.15
     4     3    11     2    520.0     520.0    29.11     46.     22.39
     4     3    11                                                             12.27
     4     3    15     1    450.0     450.0    30.61     13.      6.80
     4     3    15     2    490.0     490.0    27.09     12.      5.53
     4     3    15                                                              3.05
     4     3    19     1    420.0     420.0    26.38     24.     10.47
     4     3    19     2    470.0     470.0    22.93     21.      8.13
     4     3    19                                                              4.58
     4     3                                                                            24.95   1031.86
     4     4    16     1    430.0     430.0    39.56     96.     56.74
     4     4    16     2    460.0     460.0    34.23     80.     45.89
     4     4    16                                                             25.37
     4     4    17     1    440.0     440.0    25.23     34.     14.33
     4     4    17     2    480.0     480.0    22.77     31.     11.86
     4     4    17                                                              6.49
     4     4    20     1    450.0     450.0    56.55     36.     33.51
     4     4    20     2    490.0     490.0    47.44     33.     25.82
     4     4    20                                                             14.58
     4     4    21     1    490.0     490.0    42.63     61.     43.50
     4     4    21     2    520.0     520.0    36.26     58.     34.86
     4     4    21                                                             19.35
     4     4    22     1    450.0     450.0    43.26     13.      9.61
     4     4    22     2    500.0     500.0    35.74     12.      7.15
     4     4    22                                                              4.10
     4     4    23     1    470.0     470.0    20.42    223.     76.04
     4     4    23     2    510.0     510.0    17.37    206.     59.61
     4     4    23                                                             33.41
     4     4                                                                           103.31   4271.88
     4                                                                                                       264.83    10950.56
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*********************************************************************************************************************
                                                                     ******** PER LANDING *********   ********* PER METHOD ********
                                                                                            WEIGHTED                           WEIGHTED
                                                                                AVERAGE      AVERAGE                 AVERAGE    AVERAGE
                                                                     AVERAGE      FIXED       TRAVEL      AVERAGE      FIXED     TRAVEL
METHOD  LANDING   LANDING   LANDING      METHOD       METHOD        SKIDDING   SKIDDING    SKIDDING     SKIDDING   SKIDDING   SKIDDING
NUMBER   NUMBER    VOLUME     ACRES      VOLUME        ACRES        DISTANCE   DISTANCE    DISTANCE     DISTANCE   DISTANCE   DISTANCE

    1        1   567500.      283.                                      686.      4296.       4871.
    1                                   567500.         283.                                               666.      4296.      4871.
    2        1   162500.       65.                                      610.       792.       1587.
    2        2   405000.      218.                                      596.      2016.       3212.
    2                                   567500.         283.                                               543.      1399.      2747.
    3        1   162500.       65.                                      610.       782.       1771.
    3        2   144000.       71.                                      432.       776.       1221.
    3        3   261000.      147.                                      694.      1358.       3204.
    3                                   567500.         283.                                               579.       985.      2290.
    4        1   162500.       65.                                      610.       782.       1771.
    4        2   144000.       71.                                      432.       776.       1221.
    4        3    52000.       35.                                      535.       470.       1524.
    4        4   209000.      112.                                      624.      1007.       1583.
    4                                   567500.         283.                                               550.       759.      1540.
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                                    TRUCK
                                   TRAVEL
               METHOD   LANDING CORRECTION
               NUMBER    NUMBER     FACTOR

                    1         1       0.95
                    2         1       0.95
                    2         2       0.90
                    3         1       0.95
                    3         2       0.90
                    3         3       0.85
                    4         1       0.95
                    4         2       0.90
                    4         3       0.85
                    4         4       0.80

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*************************************************************************************************************
                                                                    ***** ALL TRUCKS WORKING TOGETHER *****
                                 CYCLE     NUMBER       TRUCK      LANDING   LANDING       METHOD      METHOD
METHOD   LANDING     TRUCK        TIME         OF        TIME     TRUCKING  TRUCKING     TRUCKING    TRUCKING
NUMBER    NUMBER    NUMBER       HOURS      LOADS       HOURS        HOURS      COST        HOURS        COST

     1         1         1        2.82      315.3      889.62
     1         1         2        2.93      283.8      830.65
     1         1                                                   429.56 17182.48
     1                                                                                     429.56    17182.48

     2         1         1        2.82       90.3      254.74
     2         1         2        2.93       81.3      237.85
     2         1                                                   123.00  4920.10
     2         2         1        2.99      225.0      672.74
     2         2         2        3.10      202.5      628.12
     2         2                                                   324.83 12993.30
     2                                                                                     447.83    17913.40

     3         1         1        2.82       90.3      254.74
     3         1         2        2.93       81.3      237.85
     3         1                                                   123.00  4920.10
     3         2         1        2.99       80.0      239.20
     3         2         2        3.10       72.0      223.33
     3         2                                                   115.50  4619.84
     3         3         1        3.10      145.0      449.80
     3         3         2        3.22      130.5      419.55
     3         3                                                   217.18  8687.21
     3                                                                                     455.68    18227.16

     4         1         1        2.82       90.3      254.74
     4         1         2        2.93       81.3      237.85
     4         1                                                   123.00  4920.10
     4         2         1        2.99       80.0      239.20
     4         2         2        3.10       72.0      223.33
     4         2                                                   115.50  4619.84
     4         3         1        3.10       28.9       89.61
     4         3         2        3.22       26.0       83.67
     4         3                                                    43.27  1730.79
     4         4         1        3.35      116.1      368.55
     4         4         2        3.47      104.5      362.75
     4         4                                                   187.60  7504.20
     4                                                                                     469.37    18774.91
*************************************************************************************************************

               **********************
               CONSTRAINT
                     CODE
               1= ROAD HR
               2= LAND HR         UPPER
               3= SKID HR         BOUND
               4= TRUK HR         VALUE

                     1             120.
                     3             600.
```

```
                                                        METHOD SUMMARY
******************************************************************************************************************************
                                        LANDING CONSTRUCTION                                                    TOTAL      METHOD
         ROAD CONSTRUCTION              AND  SYSTEM  MOVING              SKIDDING               TRUCKING        METHOD  HARVESTING
METH  ---------------------           ---------------------    ---------------------    ---------------------  HARVESTING    UNIT
 NO   HOURS      $$$   $/VOL          HOURS      $$$  $/VOL    HOURS      $$$  $/VOL    HOURS      $$$  $/VOL     COSTS      COSTS

  1      8.     170.      0.             1.      56.     0.    696.   28769.    51.    430.   17122.    30.     46177.95     81.37
  2     49.    1061.      2.             3.     191.     0.    437.   18076.    32.    448.   17913.    32.     37241.81     65.62
  3     75.    1625.      3.             4.     311.     1.    374.   15471.    27.    456.   18227.    32.     35634.3-     62.79
  4    135.    2910.      5.             6.     455.     1.    265.   10551.    19.    469.   16775.    33.     33090.45     58.31

******************************************************************************************************************************


  ITERATION NO=     1

*******************************************************************************************************************************
*    * *       *                                                                                                   *             *
*    *  *  CJ  *     95.00                                                  -21.63    -72.26    -41.35    -40.00  *    RIGHT    *
*    * B *     *                                                                                                   *             *
*    *  A *    *******************************************************************************************************    HAND     *
*      *  S *  * SELLING * METHOD  * METHOD  * METHOD  * METHOD  *          *  $/HR   *  $/HR   *  $/HR   *  $/HR   *             *
*  CB  *  I *  * PRICE $ *    1    *    2    *    3    *    4    *          *  ROADS  *  LAND   *  SKID   *  TRUCK  *  CONSTANTS  *
*        * S * *  (Y1)   *  (M1)   *  (M2)   *  (M3)   *  (M4)   *          *  (Z1)   *  (Z2)   *  (Z3)   *  (Z4)   *             *
*******************************************************************************************************************************
*            *   *                                                                                                 *             *
*    95.00 * X10*     1.00   -567.50   -567.50   -567.50   -567.50              0.00      0.00      0.00      0.00*        0.00 *
*     0.00 * X11*     0.00      7.96     49.07     75.12    134.55             -1.00      0.00      0.00      0.00*        0.00 *
*     0.00 * X12*     0.00      0.78      2.64      4.31      6.29              0.00     -1.00      0.00      0.00*        0.00 *
*     0.00 * X13*     0.00    655.75    437.15    374.16    264.63              0.00      0.00     -1.00      0.00*        0.00 *
*     0.00 * X14*     0.00    429.55    447.83    455.68    469.27              0.00      0.00      0.00     -1.00*        0.00 *
*   -21.63 * X15*     1.00      0.00      0.00      0.00      0.00              0.00      0.00      0.00      0.00*      567.50 *
*   -72.26 * X16*     0.00      1.00      1.00      1.00      1.00              0.00      0.00      0.00      0.00*        1.00 *
*   -41.35 * X17*     0.00      0.00      0.00      0.00      0.00              1.00      0.00      0.00      0.00*      120.00 *
*   -40.00 * X18*     0.00      0.00      0.00      0.00      0.00              0.00      0.00      1.00      0.00*      600.00 *
*            *   *                                                                                                 *             *
*******************************************************************************************************************************
*              *                                                                                                   *     Z -     *
*  C-BAR ROW   *     95.00      0.00      0.00      0.00      0.00            -21.63    -72.26    -41.35    -40.00*          0.*
*******************************************************************************************************************************



                                      AFTER  18 ITERATIONS THE OPTIMUM SOLUTION CONSISTED OF:
*******************************************************************************************************************************
                            ROAD     ROAD     LANDING CONST      LANDING CONST                                                  TOTAL
METHOD        METHOD       CONST    CONST     AND      SYSTEM    AND     SYSTEM   SKIDDING   SKIDDING   TRUCKING   TRUCKING    METHOD
   #     PROPORTION        HOURS    COSTS               HOURS             COSTS      HOURS      COSTS      HOURS      COSTS     COSTS

   4           0.76        101.6    2198.                 4.8              343.       200.      8269.      354.5     14178.    24989.
   3           0.24         18.4     398.                 1.1               76.        92.      3788.      111.6      4463.     8725.
         ------- ---------- --------             ----------        --------- ---------- ---------- ----------   -------- ---------
TOTALS:        1.00        120.0    2596.                 5.8              419.       292.     12057.      466.0     18641.    33713.
*******************************************************************************************************************************

*************************************************************************************************
(A) TOTAL DELIVERD PRICE OF HARVESTED TIMBER:           53913.       UNIT PRICE:          95.00
(B) TOTAL HARVESTING COSTS (THOSE CONSIDERED):          33713.       UNIT COSTS:          59.41
                                                       -------                           -------
                        DIFFERENCE: (A)-(B):            20199.                            35.59
*************************************************************************************************


  ITERATION NO=   18

*******************************************************************************************************************************
*    * *       *                                                                                                   *             *
*    *  *  CJ  *     95.00                                                  -21.63    -72.26    -41.35    -40.00  *    RIGHT    *
*    * B *     *                                                                                                   *             *
*    *  A *    *******************************************************************************************************    HAND     *
*      *  S *  * SELLING * METHOD  * METHOD  * METHOD  * METHOD  *          *  $/HR   *  $/HR   *  $/HR   *  $/HR   *             *
*  CB  *  I *  * PRICE $ *    1    *    2    *    3    *    4    *          *  ROADS  *  LAND   *  SKID   *  TRUCK  *  CONSTANTS  *
*        * S * *  (Y1)   *  (M1)   *  (M2)   *  (M3)   *  (M4)   *          *  (Z1)   *  (Z2)   *  (Z3)   *  (Z4)   *             *
*******************************************************************************************************************************
*            *   *                                                                                                 *             *
*     0.00 * X 1*     1.00      0.00      0.00      0.00     -0.00             -0.00     -0.00     -0.00     -0.00*      567.50 *
*     0.00 * Y 7*    -0.00      1.28      0.79      0.00     -0.00             -0.00      1.00     -0.00     -0.00*        5.81 *
*     0.00 * X 8*    -0.00   -197.89    -15.05      0.00     -0.00             -0.00     -0.00      1.00     -0.00*      291.59 *
*     0.00 * X 9*    -0.00     10.62      1.84      0.00     -0.00             -0.00     -0.00     -0.00      1.00*      466.02 *
*   -40.00 * X18*    -0.00    197.88     15.08      0.00     -0.00             -0.00     -0.00     -0.00     -0.00*      308.40 *
*     0.00 * X 5*    -0.00     -1.13     -0.44      0.00      1.00             -0.00     -0.00     -0.00     -0.00*        0.76 *
*     0.00 * X 4*     0.00      2.13      1.44      1.00      0.00              0.00      0.00      0.00      0.00*        0.24 *
*   -72.26 * X16*    -0.00     -0.00      0.00      0.00     -0.00             -0.00     -0.00     -0.00     -0.00*        0.00 *
*     0.00 * X 6*    -0.00      0.00     -0.00      0.00     -0.00              1.00     -0.00     -0.00     -0.00*      120.00 *
*            *   *                                                                                                 *             *
*******************************************************************************************************************************
*              *                                                                                                   *     Z =     *
*  C-BAR ROW   *      0.00  -7665.56   -492.88      0.00      0.00              0.00      0.00      0.00      0.00*      20199.*
*******************************************************************************************************************************
****************                                                             ***                                   ************
****************                                                             ***                                   ************
****************          ABOVE VALUES IN C-BAR ROW                          ***       ABOVE VALUES IN C-BAR ROW   ************
****************          ARE PENALTY COSTS                                  ***       ARE SHADOW PRICES           ************
****************                                                             ***                                   ************
****************                                                             ***                                   ************
*******************************************************************************************************************************
```

```
                         SENSITIVITY ANALYSIS

          NOTE: VARIABLE CODE NUMBERS USED IN SENSITIVITY
          ANALYSIS ARE NOT EASY TO CORRELATE WITH OUTPUT
          COLUMNS AND ROWS FROM LP MATRIX

          USERS FAMILIAR WITH LP SHOULD MAKE CHANGES IN
          INPUT COSTS (CJ) AND RESOURCE LIMITS (EJ) TO
          BECOME FAMILIAR WITH THE SENSITIVITY ANALYSIS AS IT
          APPLIES TO THE CONVEX-ISOQUANT-METHOD FORMULATION
          USED IN L-O-S-T


SHADOW PRICES ARE CHANGE IN OBJECTIVE FUNCTION VALUE PER UNIT CHANGE
     IN RIGHT HAND SIDE CONSTRAINTS.

PENALTY COSTS ARE CHANGE IN OBJECTIVE FUNCTION VALUE PER UNIT
     INCREASE IN NON-BASIC VARIABLES.

RANGES ON C(J) REPRESENT LIMITING VALUES OF COST COEFFICIENTS THAT
     WILL NOT CHANGE THE OPTIMUM SOLUTION


 RANGES ON B(I) REPRESENT LIMITING VALUES OF RIGHT HAND SIDE CONSTRAINTS
     THAT WILL NOT CHANGE OPTIMUM BASIC VARIABLES.


          NON-BASIC           PENALTY
          VARIABLES            COST

             10               -67.947
             11               -64.426
             12               -72.260
             13               -41.350
             14               -40.000
             15               -27.053
             17               -42.756
              2             -7665.563
              3              -492.884


            ROW               SHADOW
           NUMBER             PRICES

              1                 0.000
              2                 0.000
              3                 0.000
              4                 0.000
              5                 0.000
              6                 0.000
              7                 0.000
              8                 0.000
              9                 0.000


   RANGES ON NON-BASIC C(J)

          VARIABLE          LOWER LIMIT

             10                67.947
             11                64.426
             12                72.260
             13                41.350
             14                40.000
             15                27.053
             17                42.756
              2              7665.563
              3               492.884


   RANGES ON BASIC C(J)

          VARIABLE          LOWER LIMIT         UPPER LIMIT

             16            -38559.850          15353.200
             18               -23.267             30.446
              1                67.947         999999.000
              4              -342.694           2543.590
              5             -2543.590           1124.023
              6               -64.426          17373.890
              7              -693.435              0.000
              8               -71.932            -13.043
              9               -74.861              0.101


   RANGES ON B(I)

             I              LOWER LIMIT         UPPER LIMIT

             1                567.500            567.500
             2                274.124            132.501
             3            -999999.000              1.923
             4                504.219            501.998
             5            -999999.000            440.392
             6                 -0.000             -0.000
             7                  1.000         999999.000
             8                274.124            132.501
             9                504.219         999999.000
```

Appendix 8—L-O-S-T Program Listing

```
//LOST     JOB (UFS26JK,153),'KOGER',NOTIFY=UFS26JK,MSGCLASS=A,
//         MSGLEVEL=(1,1)
/*ROUTE PRINT LOCAL
/*JOBPARM T=21,L=40K
//  EXEC WATFIV
//WATFIV.SYSIN DD *
/JOB KOGER,PAGES=50,S=1000000,TIME=25
      DIMENSION DZRHP(5),DZREF(5),DZRHC(5),SKDHP(10),SKDWT(10),
     1SKDEF(10),SKDHC(10),TKTENW(10),TKTLNW(10),
     2TKTEWD(10),TKTLWD(10),TKFTPC(10),TKEF(10),TKVOL(10),
     3TKHC(10),ILAND(10),ATITLE(16),
     4INRSBM(20),JNAREA(4,10),DSFTB(4,10)
      DIMENSION AREAV(4,8,25),AREAA(4,8,25),AREAMN(4,8,25),
     1AREAMX(4,8,25),AREAFD(4,8,25),AREACF(4,8,25),
     2AREATS(4,8,25),AREADI(4,8,25),AREAFT(4,8,25),
     3VOLML(4,10),VOLBM(4),TKTCF(4,10)
     4,AREA(4,8,25),VOLMA(4,10),ACRBM(4)
     5,ASKDBL(4,8),FSKDBL(4,8),WSKDBL(4,8),ASKDBM(4),
     6FSKDBM(4),WSKDBM(4)
      DIMENSION LOGMET(11,20),SUM(10,10,14),SUMMET(2,50),CI(25)
      COMMON C(25),P(25),OMZ(25),A(25,25),ZJ(25),IVAR(25),PCOST(25)
     1,SHADO(25),CL(25),CU(25),CUP(25),CLO(25),BUP(25),BLO(25)
     2,B(25),CC(25),JVAR(25),IARR(4),PROP(4),RC(4),LD(4),SK(4),
     3TK(4)
      REAL LOGMET,LD,LAMDMC
CJK
CJK  CJK COMMENT CARDS BY JERRY KOGER
CJK  CWC COMMENT CARDS BY WADE CULVER
CJK  C   COMMENT CARDS BY RAVINDRAN, ETC.
CJK
CJK
CJK
CJK      L-O-S-T IS DIVIDED INTO 2 SECTIONS; THE FIRST SECTION
CJK      CALCULATES LOGGING COSTS AND THE SECOND SECTION USES
CJK      THESE COSTS AS INPUT FOR THE LINEAR PROGRAM
CJK
CJK
CJK
CJK          #########  SECTION 1  ########################
CJK
CJK
CJK
CJK  CTRAD CONVERTS DEGREES TO RADIANS; CTDEG CONVERTS RADIANS
CJK  TO DEGREES;  KR=5 FOR READ
CJK  READ(KR,YY); KW=6 FOR WRITE  WRITE(KW,ZZ)
CJK
      CTRAD = 0.01745329
      CTDEG = 57.29578
      KR=5
      KW = 6
CJK
CJK
CJK CONPTB=CONVERSION POUNDS TO BOARD FEET,VALUE OF 0.11951
CJK TAKEN FROM TVA TECHNICAL NOTE 846, 1982 BY JERRY KOGER
CJK "LOG LOADING METHODS AND COSTS IN THE TENNESSEE VALLEY
CJK  REGION   PAGE 20
CJK  CONBTB=CONVERSION FROM BOARD FEET TO BOARD FEET 1/4 INT
CJK  CONCTB=CONVERSION FROM CORDS TO BOARD FEET
CJK  CONUTB= CONVERSION FROM CUBIC FEET TO BOARD FEET
CJK   THESE CONVERSIONS ARE ONLY USED IN SKIDDING TIME EQUATIONS
CJK
      CONPTB=0.11951
      CONBTB=1.0
      CONCTB=687.2746
      CONUTB=5.7947
CJK
CJK
CJK  **************** CARD TYPE 1 ******************************
CJK
CJK
      READ(KR,70) (ATITLE(ITR),ITR=1,16)
   70 FORMAT(16A4)
      WRITE(KW,80) (ATITLE(ITW),ITW=1,16)
   80 FORMAT(1H1,/,2X,'TITLE L-O-S-T  RUN=',4X,16A4)
CJK

CJK
CJK  **************** CARD TYPE 2 ********************************
CJK
CJK
CJK  NMETH=# OF METHODS; NOZR=#OF DOZERS; NSKD=# OF SKIDDERS;
CJK  NTRK= # OF TRUCKS; ICTRAT=# OF USER SUPPLIED CONSTRAINTS
CJK  FOR LP ANALYSIS;  LPCDE=LP OUTPUT MATRIX DEBUG CODE
CJK
      READ(KR,90)NMETH,NDZR,NSKD,NTRK,ICTRAT,ILPANA,LPCDE
   90 FORMAT(I2,1X,I2,1X,I2,1X,I2,1X,I1,1X,I1,1X,I1)
      WRITE(KW,100)NMETH,NDZR,NSKD,NTRK
  100 FORMAT(3X,'NUMBER OF METHODS=',2X,I3,/,4X,'NUMBER OF',
     11X,'DOZERS=',2X,I3,/,2X,'NUMBER OF SKIDDERS=',2X,I3,/,
     24X,'NUMBER OF TRUCKS=',2X,I3)
      WRITE(KW,125)ILPANA,LPCDE,ICTRAT
  125 FORMAT(4X,'LP ANALYSIS CODE=',3X,I2,/,6X,'LP OUTPUT CODE=',
     13X,I2,/,2X,'# USER CONSTRAINTS=',3X,I2)
      M=ICTRAT+5
      M2=NMETH+ICTRAT+10
CJK
CJK
CJK  ZERO OUT AREA VOLUME ARRAY
CJK
CJK
      DO 150 IZAVM=1,NMETH
      DO 140 IZAVL=1,8
      DO 130 IZAVA=1,25
      AREAV(IZAVM,IZAVL,IZAVA)=0.0
  130 CONTINUE
  140 CONTINUE
  150 CONTINUE
CJK
CJK
CJK
CJK  ZERO OUT SELECTED ARRAYS USED IN LP SECITON OF LOST
CJK
      DO 170 IDL21=1,25
      DO 160 IDL22=1,25
      A(IDL22,IDL21)=0.0
  160 CONTINUE
  170 CONTINUE
      DO 185 IZOUT1=1,11
      DO 180 IZOUT2=1,20
      LOGMET(IZOUT1,IZOUT2)=0.0
  180 CONTINUE
  185 CONTINUE
      DO 190 IZOUT3=1,25
      CI(IZOUT3)=0.0
      C(IZOUT3)=0.0
      P(IZOUT3)=0.0
      OMZ(IZOUT3)=0.0
      ZJ(IZOUT3)=0.0
      IVAR(IZOUT3)=0.0
      PCOST(IZOUT3)=0.0
      SHADO(IZOUT3)=0.0
      CL(IZOUT3)=0.0
      CU(IZOUT3)=0.0
      CUP(IZOUT3)=0.0
      CLO(IZOUT3)=0.0
      BUP(IZOUT3)=0.0
      BLO(IZOUT3)=0.0
      B(IZOUT3)=0.0
      CC(IZOUT3)=0.0
      JVAR(IZOUT3)=0.0
  190 CONTINUE
CJK
CJK
CJK **************  CARD TYPE 3 **********************************
CJK
CJK
CJK  IUNIT=UNITS CODE FOR BOARD FEET CORDS, ETC; HARVOL=
CJK  VOLUME HARVEST; PRODPC=PRODUCT SELLING PRICE;
CJK  SYSMHC=SYSTEM MOVE HOURLY COST; DFTBTM=DISTANCE IN MILES
CJK  FROM TRACT BOUNDARY TO MILL
CJK
      READ(KR,200)IUNIT,HARVOL,PRODPC,SYSMHC,DFTBTM
  200 FORMAT(I1,1X,F10.0,1X,F7.2,1X,F7.2,1X,F5.1)
      IF(IUNIT.EQ.1)WRITE(KW,250)HARVOL
  250 FORMAT(2X,'HARVEST VOLUME=',22X,F11.0,2X,'POUNDS')
      IF(IUNIT.EQ.2)WRITE(KW,300)HARVOL
  300 FORMAT(2X,'HARVEST VOLUME=',22X,F11.0,2X,'INT. BOARD FEET')
      IF(IUNIT.EQ.3)WRITE(KW,350)HARVOL
  350 FORMAT(2X,'HARVEST VOLUME=',22X,F11.0,2X,'CUBIC FEET')
      IF(IUNIT.EQ.4)WRITE(KW,360)HARVOL
  360 FORMAT(2X,'HARVEST VOLUME=',22X,F11.0,2X,'CORDS')
      WRITE(KW,400)PRODPC,SYSMHC,DFTBTM
  400 FORMAT(2X,'PRICE IN SELLING UNITS ($)=',15X,F8.2,/,2X,
     1'HOURLY LANDING MOVE COST ($)=',13X,F8.2,/,2X,
     2'DISTANCE FROM WOODS EDGE TO MILL (MILES)=',2X,F6.1)
      WRITE(KW,450)
  450 FORMAT(/,2X,29('*'),/,2X,'DOZER',2X,'DOZER',
     13X,'DOZER',3X,'HOURLY',/,1X,'NUMBER',5X,'HP',3X,'EFFIC',
     25X,'COST',/)
      DO 475 IDLOO=1,NMETH
      IF(IUNIT.EQ.1)LOGMET(1,IDLOO)=-HARVOL/2000.0
      IF(IUNIT.EQ.2)LOGMET(1,IDLOO)=-HARVOL/1000.0
      IF(IUNIT.EQ.3)LOGMET(1,IDLOO)=-HARVOL/100.0
      IF(IUNIT.EQ.4)LOGMET(1,IDLOO)=-HARVOL/1.0
  475 CONTINUE
      SMDZHC=0.0
      DO 600 IDL01=1,NDZR
CJK
CJK
CJK ******************CARD TYPE 4    ***********************
CJK
CJK
CJK  DZRPH()=DOZER HORSEPOWER; DZREF()=DOZER EFFICEINCY;
CJK  DZRHC()=DOZER HOURLY COST; SMDZHC=SDOZER
CJK  HOURLY COST
CJK
      READ(KR,500)DZRHP(IDL01),DZREF(IDL01),DZRHC(IDL01)
  500 FORMAT(F4.0,1X,F4.2,1X,F6.2)
      SMDZHC=SMDZHC+DZRHC(IDL01)
      WRITE(KW,550)IDL01,DZRHP(IDL01),DZREF(IDL01),DZRHC(IDL01)
  550 FORMAT(4X,I3,2X,F5.0,3X,F5.2,2X,F7.2)
  600 CONTINUE
      WRITE(KW,650)SMDZHC
  650 FORMAT(/,2X,29('*'),/,23X,F8.2)
      WRITE(KW,700)
  700 FORMAT(2(/),2X,51('*'),/,46X,'SKIDDER',/,
     12X,'SKIDDER',6X,'SKIDDER',3X,'SKIDDER',2X,
     2'SKIDDER',6X,'HOURLY',/,3X,'NUMBER',3X,
     3'HORSEPOWER',4X,'WEIGHT',4X,'EFFIC',8X,'COST',/)
      SMSKHC=0.0
      DO 850 IDL02=1,NSKD
CJK
CJK
CJK  *************** CARD TYPE 5 ***************************
CJK
CJK
CJK  SKDHP()=SKIDDER HORSEPOWER; SKDWT()=SKIDDER WEIGHT;
CJK  SKDEF()=SKIDDER EFFICIENCY; SMSKHC=SUM OF ALL SKIDDERS
CJK  HOURLY COSTS
CJK
      READ(KR,750)SKDHP(IDL02),SKDWT(IDL02),SKDEF(IDL02)
     1,SKDHC(IDL02)
  750 FORMAT(F4.0,1X,F6.0,1X,F4.2,1X,F6.2)
      SMSKHC=SMSKHC+SKDHC(IDL02)
      WRITE(KW,800)IDL02,SKDHP(IDL02),SKDWT(IDL02),SKDEF(IDL02),
     1SKDHC(IDL02)
  800 FORMAT(5X,I5,7X,F6.0,2X,F8.0,1X,F7.2,5X,F7.2)
  850 CONTINUE
      WRITE(KW,900)SMSKHC
  900 FORMAT(/,2X,51('*'),/,45X,F8.2)
      WRITE(KW,950)
  950 FORMAT(2(/),2X,78('*')/,9X,'** NON-WOODS **',
     13X,'***** WOODS',
     21X,'****',/,9X,'TRAVEL',3X,'TRAVEL',3X,'TRAVEL',4X,
     3'TRAVEL',3X,'FIXED',/,10X,'EMPTY',3X,'LOADED',4X,'EMPTY',
     44X,'LOADED',4X,'TIME',14X,'CYCLE',4X,'TRUCK',/,2X,
     5'TRUCK',3X,'SPEED',4X,'SPEED',4X,'SPEED',5X,'SPEED',
     65X,'PER',3X,'TRUCK',6X,'TRUCK',3X,'HOURLY',/,1X,
     7'NUMBER',5X,'MPH',6X,'MPH',6X,'MPH',7X,'MPH',4X,'LOAD',
     83X,'EFFIC',5X,'VOLUME',5X,'COST',/)
      SMTKHC=0.0
      DO 1100 IDL03=1,NTRK
CJK
CJK
CJK  *************  CARD TYPE 6  ******************************
CJK
CJK
CJK  TKTENW()=TRUCK TRAVEL SPEED EMPTY OVER NON-WOODS ROAD
CJK  TKTLNW()=TRUCK TRAVEL SPEED LOADED OVER NON-WOODS ROAD
CJK  TKTEWD()=TRUCK TRAVEL SPEED EMPTY OVER WOODS ROAD
CJK  TKTLWD()=TRUCK TRAVEL SPEED LOADED OVER WOODS ROAD
CJK  TKFTPC()=FIXED TIME PER TRUCK CYCLE IN MINUTES
CJK  TKEF()=TRUCK EFFICIENCY (IE 0.80)
CJK  TKVOL()=TRUCK VOLUME
CJK  TRAVEL SPEEDS ARE IN MPH
CJK  SMTKHC=SUM OF ALL TRUCKS HOURLY COST
CJK
CJK
      READ(KR,1000)TKTENW(IDL03),TKTLNW(IDL03),TKTEWD(IDL03),
     1TKTLWD(IDL03),TKFTPC(IDL03),TKEF(IDL03),TKVOL(IDL03),
     2TKHC(IDL03)
 1000 FORMAT(5(F4.1,1X),F4.2,1X,F10.2,1X,F6.2)
      SMTKHC=SMTKHC+TKHC(IDL03)
      WRITE(KW,1050)IDL03,TKTENW(IDL03),TKTLNW(IDL03),
     1TKTEWD(IDL03),TKTLWD(IDL03),TKFTPC(IDL03),TKEF(IDL03),
     2TKVOL(IDL03),TKHC(IDL03)
 1050 FORMAT(2X,I4,3X,F6.2,3X,F6.2,3X,F6.2,4X,F6.2,2X,F6.2,2X,
     1F6.2,1X,F10.2,2X,F7.2)
 1100 CONTINUE
      WRITE(KW,1150)SMTKHC
 1150 FORMAT(1(/),2X,78('*'),/,71X,F8.2)
      WRITE(KW,1175)
 1175 FORMAT(1H1,/,2X,26('*'),/,12X,'NUMBER',4X,'NUMBER',/,
     12X,'METHOD',6X,'ROAD',8X,'OF',/,2X,'NUMBER',2X,
     2'SEGMENTS',2X,'LANDINGS',/)
      DO 1250 IDL04=1,NMETH
CJK
CJK
CJK  *************  CARD TYPE 7  ****************************
CJK
CJK
CJK  IMETH=METHOD NUMBER; IRDSEG=NUMBER OF ROAD SEGMENTS
CJK  FOR THIS METHOD; ILAND()= NUMBER OF LANDINGS FOR THIS METHOD
CJK
      READ(KR,1200)IMETH,IRDSEG,ILAND(IDL04)
 1200 FORMAT(I1,1X,I2,1X,I2)
      INRSBM(IDL04)=IRDSEG
      WRITE(KW,1225)IMETH,IRDSEG,ILAND(IDL04)
 1225 FORMAT(4X,I4,6X,I4,6X,I4)
 1250 CONTINUE
      WRITE(KW,1275)
 1275 FORMAT(/,2X,26('*'),//)
      WRITE(KW,1300)
 1300 FORMAT(2(/),2X,43('*'),/,22X,'NUMBER',/,
     12X,'METHOD',3X,'LANDING',2X,6X,'OF',5X,'MAXIMUM AREA',/,
     22X,'NUMBER',4X,'NUMBER',5X,'AREAS',5X,'CODE  NUMBER',/)
 1325 CONTINUE
CJK
CJK
CJK   ******************  CARD TYPE 8  ********************
CJK
CJK
CJK   JMN=METHOD NUMBER; JLN=LANDING NUMBER;
CJK   JNA= NUMBER OF AREAS
CJK   JMAN=MAXIMUM VALUE OF AREA CODE NUMBER ; IS THE SAME
CJK   AS JNA ONLY IF AREAS ARE CODED IN NUMERICAL SEQUENCE
CJK
CJK
CJK
      READ(KR,1350)JMN,JLN,JNA,JMAN
 1350 FORMAT(I1,1X,I2,1X,I2,1X,I2)
      IF(JMN.EQ.0)GO TO 1400
      JNAREA(JMN,JLN)=JMAN
      WRITE(KW,1375)JMN,JLN,JNA,JMAN
 1375 FORMAT(4X,I4,6X,I4,6X,I4,14X,I3)
      GO TO 1325
 1400 WRITE(KW,1425)
 1425 FORMAT(/,2X,43('*'),2(/))
      WRITE(KW,1450)
 1450 FORMAT(2(/),2X,127('*'),/,59X,'CUT',3X,'FILL',4X,'ROAD',
     1/,2X,'METHOD',2X,'SEGMENT',3X,'DOZER',5X,'ROAD',3X,
     2'ROAD',3X,'ROAD',3X,'SIDE',2X,'SLOPE',2X,'SLOPE',4X,'TYPE',
     34X,'CUBIC',
     44X,'ACRES',2X,'SEGMENT',2X,'SEGMENT',2X,'METHOD',2X,
     5'METHOD',/,2X,'NUMBER',3X,'NUMBER',2X,'NUMBER',3X,
     6'LENGTH',2X,'WIDTH',2X,'SLOPE',2X,'SLOPE',2X,'RATIO',2X,
     7'RATIO',4X,'CODE',4X,'YARDS',2X,'CLEARED',4X,'HOURS',
     85X,'COST',3X,'HOURS',4X,'COST',/)
CJK
CJK
CJK      START OF DO LOOP BY METHOD++++ROAD CONSTRUCTION TIMES
CJK
CJK
      DO 1850 IDL05=1,NMETH
      SMRDSL=0.0
      SMRDCY=0.0
      SMRDNA=0.0
      SMRDHR=0.0
      SMRDHM=0.0
      IDLB01=INRSBM(IDL05)
      IDLB02=INRSBM(IDL05)
      IF(IDLB01.EQ.0)IDLB02=1
CJK
CJK
CJK      START OF DO LOOP BY ROAD SEGMENT+++ROAD CONSTRUCTION TIMES
CJK
CJK
      DO 1650 IDL06=1,IDLB02
CJK
CJK
CJK  *************** CARD TYPE 10  *************************
CJK
CJK
CJK   ROADSL=ROAD SEGMENT LENGTH IN FEET; ROADSW=ROAD
CJK   SEGMENT WIDTH ISEGMENT SLOPE IN PERCENT
CJK   OF DIRECTION BUILT; ROADSS=ROAD SEGMENT SIDE SLOPE IN
CJK   IN PERCENT; ROADCR=ROAD SEGMENT CUT RATI; ROADFR=
CJK   ROAD SEGMENT FILL RATIO; ROADTY=ROAD DIFFICULTY CODE
CJK
CJK
CJK
      READ(KR,1500)ROADSL,ROADSW,ROADSP,ROADSS,ROADCR,ROADFR,ROADTY
 1500 FORMAT(F7.0,1X,F4.1,1X,F5.0,1X,F5.0,1X,F5.2,1X,F5.2,1X,F5.0)
      IF(IDLB01.EQ.0)GO TO 1700
      IF(ROADSL.EQ.0.0)GO TO 1700
CJK  FOLLOWING EQUATIONS COMPUTE CUBIC YARDS OF EARTH REMOVED
CJK  IN ROAD BUILDING BASED ON EQUATIONS BY JOHN K. BOWMAN,
CJK  ROBERT B. MCCREA, AND CARL L. FONNESBECK "A METHOD
CJK  OF FIELDDESIGN APPLIED TO FOREST ROADS" PAGE 194,
CJK  IN: LOW VOLUME ROADS, SPECIAL REPORT 160, TRANSPORTATION
CJK  RESEARCH BORAD, NATIONAL RESEARCH COUNCIL, NATIONAL
CJK  ACADEMY OF SCIENCES, WASHINGTON DC, 1975
CJK
CJK
CJK
CJK    SHRIKF HAS A VALUE OF 0.20 IN ORDER TO OBTAIN THE VALUES
CJK    FOR CUBIC YARDS AND ACRES GIVEN IN THE 4 TH EDITION OF
CJK    "ENGINEERING FIELD TABLES" USDA FOREST SERVICE AND BLM
CJK    JULY 1976,  (EM7100-10)
CJK
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CJK
      SHRIKF=0.20
      ROADSD = ATAN(ROADSS/100.0)*CTDEG
      ROADCS = ATAN(ROADCR)*CTDEG
      ROADSF=1.000-(0.014*ROADSP)-(0.00019*ROADSP*ROADSP)
      ROADFS = ATAN(ROADFR)*CTDEG
      CCCC = COTAN(ROADSD*CTRAD)
      A0 = COTAN(ROADSD*CTRAD)-ROADCR
      A1 = A0*(1+SHRIKF)
      A2 = COTAN(ROADSD*CTRAD)-ROADFR
      A3 = SQRT(A1/A2)
      A4 = ROADSW/2.0*(A3-1.0)
      BK = A4/(A3+1.0)
      DF = ((ROADSW/2.0)-BK)/(COTAN(ROADSD*CTRAD)-ROADFR)
      DC = (BK+ROADSW/2.0)/(COTAN(ROADSD*CTRAD)-ROADCR)
      THETA = 180.0-ROADCS
      BASE1 = DC/TAN(ROADSD*CTRAD)
      THETA = 180.0-ROADFS
      AREAF = (1.0/2.0)*(ROADSW/2.0)*ROADFR*SIN(THETA*CTRAD)
      BASE2 = DF/TAN(ROADSD*CTRAD)
      BASE = BASE1+BASE2
      BASECU=DC/TAN(ROADCS*CTRAD)
      AREAC=(0.5*((ROADSW/2.0)+BK+BASECU)*DC)-(0.5*BASECU*DC)
      ROADNA = (BASE*1000.0)/43560.0
      ROADCY = (AREAC*1000.0)/27.0
      CUBEYD=(AREAC*ROADSL)/27.0
      ACRES=(BASE*ROADSL)/43560.0
      SMRDSL=SMRDSL+ROADSL
      SMRDCY=SMRDCY+CUBEYD
      SMRDNA=SMRDNA+ACRES
      SMRDSH=0.0
CJK
CJK
CJK    START OF DO LOOP FOR DOZERS++++ROAD CONSTRUCTION TIMES
CJK
CJK
      DO 1600 IDL07=1,NDZR
CJK
CJK   SEGRDH=HOURS TO BUILD THIS ROAD SEGMENT; BASED ON EQUATION
CJK   BY JERRY KOGER "FACTORS AFFECTING THE CONSTRUCTION AND
CJK   COST OF LOGGING ROADS"  TVA TECHNICAL NOTE B27, TENNESSEE
CJK   VALLEY AUTHORITY, NORRIS, TN, 37828  PAGE 30, 1978
CJK   EQUATION MODIFIED BY LATER ANALYSIS INTO DIFFERENT ROAD
CJK   TYPES... SEE FACTOR ROADTY FOR THIS ADJUSTMENT
CJK   ROADCY= CUBIC YARDS OF EARTH PER 1000 FT OF ROAD;
CJK   ROADNA= NUMBER OF ACRES OF CLEARED RIGHT OF WAY PER
CJK   100SLOPE CORRECTION FACTOR TO
CJK   PRODUCE VALUES GIVEN IN FIGURE 22 OF TVA TECH NOTE B27
CJK
CJK
      SEGRDH=(ROADSL/ROADTY)*
     1(0.524*SQRT(ROADCY/(ROADSF*DZRHP(IDL07)))+
     212.668*SQRT(ROADNA/(ROADSF*DZRHP(IDL07)))))/DZREF(IDL07)
      SMRDSH=SMRDSH+(1.0/SEGRDH)
      SEGRDC=SEGRDH*DZRHC(IDL07)
      WRITE(KW,1550)IDL05,IDL06,IDL07,ROADSL,ROADSW,ROADSP,
     1ROADSS,ROADCR,ROADFR,ROADTY,CUBEYD,ACRES,SEGRDH,SEGRDC
 1550 FORMAT(4X,I4,5X,I4,4X,I4,1X,F8.0,1X,F6.1,1X,F6.0,1X,
     1F6.0,2X,F5.2,2X,F5.2,2X,F6.0,1X,F8.1,1X,F8.1,1X,F8.1,F9.2)
 1600 CONTINUE
CJK
CJK
CJK   SMRDHS=NUMBER OF HOURS TO BUILD THIS ROAD SEGMENT
CJK   IF ALL DOZERS WORKED TOGETHER
CJK
CJK
      SMRDHS=1.0/SMRDSH
      SMRDHM=SMRDHM+SMRDHS
      SMRDCS=SMRDHS*SMDZHC
      SMRDCM=SMRDHM*SMDZHC
      IF(NDZR.GT.1)WRITE(KW,1625)IDL05,IDL06,SMRDHS,SMRDCS
 1625 FORMAT(4X,I4,5X,I4,81X,F6.1,F9.2)
 1650 CONTINUE
 1700 CONTINUE
      IF(IDLB01.EQ.0)SMRDHM=0.0
      IF(IDLB01.EQ.0)SMRDCM=0.0
      LOGMET(2,IDL05)=SMRDHM
      WRITE(KW,1800)IDL05,SMRDSL,SMRDCY,SMRDNA,
     1SMRDHM,SMRDCM
 1800 FORMAT(4X,I4,17X,F9.0,43X,F9.1,1X,F8.1,18X,F8.1,F8.0,//)
 1850 CONTINUE
      WRITE(KW,1900)
 1900 FORMAT(/,127('*'))
      WRITE(KW,1950)
 1950 FORMAT(1H1,//,2X,127('*'),/,110X,'WEIGHTED',5X,'METHOD',/,
     119X,'DISTANCE',3X,'LANDING',2X,'AVERAGE',10X,'HOURLY',
     211X,'LANDING',3X,'LANDING',3X,'SYSTEM',3X,'SYSTEM',
     32X,'BUILDING',5X,'MOVE &',/,2X,'METHOD',2X,'LANDING',6X,
     4'FROM',6X,'SIZE',6X,'CUT',3X,'DOZER',3X,'DOZER',3X,'EFFIC',
     52X,'BUILDING',2X,'BUILDING',5X,'MOVE',5X,'MOVE',2X,
     6'& MOVING',4X,'LANDING',
     6/,2X,'NUMBER',3X,'NUMBER',2X,'BOUNDARY',5X,
     7'ACRES',4X,'DEPTH',6X,'HP',4X,'COST',4X,'CODE',5X,
     8'HOURS',6X,'COST',4X,'HOURS',5X,'COST',5X,'HOURS',
     97X,'COST',/)
CJK
CJK
CJK   *********** CARD TYPE 11 *****************************
CJK
CJK
CJK    ILDZR=INPUT ORDER NUMBER OF DOZER USED TO BUILD
CJK     LANDINGS... ONLY ONE DOZER IS ALLOWED TO BUILD
CJK    LANDINGS
CJK
CJK
CJK
      READ(KR,2000)ILDZR
 2000 FORMAT(I1)
CJK
CJK
CJK       START OF DO LOOP FOR METHODS++++ LANDING CONSTRUCTION TIMES
CJK
CJK
      DO 2200 IDL08=1,NMETH
      SMHRLA=0.0
      SMCBL=0.0
      SMSYMH=0.0
      SMCML=0.0
      IDLB03=ILAND(IDL08)
CJK
CJK
CJK     START OF DO LOOP FOR LANDINGS+++++LANDING CONSTRUCTION TIMes
CJK
CJK
      DO 2150 IDL09=1,IDLB03
CJK
CJK
CJK   ************* CARD TYPE 12  *************************
CJK
CJK
CJK   DSFTB()=DISTANCE IN FEET FROM TRACT BOUNDARY TO THIS LANDIG
CJK   ACRESL= ACRES IN THIS LANDING... SIZE OF LANDING
CJK   CUTL=AVERAGE CUT DEPTH OF EARTH REMOVED IN BUILDING LANDING
CJK   EFFL=DEFFICIENCY FACTOR FOR THIS LANDING (IE 0.80)
CJK   SYSMHR=SYSTEM MOVE TIME IN HOURS TO THIS LANDING; NOT A
CJK   MOVE IN TIME BUT A MOVE BETWEEN LANDING TIME
CJK
CJK
      READ(KR,2050)DSFTB(IDL08,IDL09),ACRESL,CUTL,EFFL,SYSMHR
 2050 FORMAT(F8.0,1X,F4.1,1X,F4.1,1X,F4.2,1X,F5.1)
      APPLL=(ACRESL*43560.0)/26.70
      APPCYL=((APPLL*CUTL*26.70)/27.0)/(APPLL/1000.0)
      APPACL=(((APPLL*26.70)/43560.0))/(APPLL/1000.0)
CJK
CJK    LOGIC WAS TO CONVERT LANDING SIZIN ACRES TO AN
CJK    EQUIVALENT LENGHT OF ROAD AND THEN USE ROAD
CJK    CONSTRUCTION EQUATION IN TVA TECH NOTE B27
CJK    APPCYL=APPROXIMATE NUMBER OF CUBIC YARDS
CJK    APPACL=APPROXIMATED NUMBER OF ACRES IF CONVERTED
CJK           FROM LANDING ACRES TO ROAD LENGTH ACRES
CJK    HRTBL=HOURS TO BUILD LANDING
CJK
CJK
      HRTBL=(APPLL/3000.0)*(0.524*SQRT(APPCYL/DZRHP(ILDZR))+
     1(12.668*SQRT(APPACL/DZRHP(ILDZR))))/(DZREF(ILDZR)*EFFL)
      SMHRLA=SMHRLA+HRTBL
      CBL=HRTBL*DZRHC(ILDZR)
      SMCBL=SMCBL+CBL
      CML=SYSMHR*SYSMHC
      SMCML=SMCML+CML
      SMSYMH=SMSYMH+SMCML
      WRITE(KW,2100)IDL08,IDL09,DSFTB(IDL08,IDL09),ACRESL,CUTL,
     1DZRHP(ILDZR),DZRHC(ILDZR),EFFL,HRTBL,CBL,SYSMHR,CML
 2100 FORMAT(4X,I4,5X,I4,1X,F9.0,4X,F6.1,3X,F6.1,2X,F6.0,
     11X,F7.2,2X,F6.2,1X,F9.2,1X,F9.2,2X,F7.1,1X,F8.2)
 2150 CONTINUE
      WLBH1=DZRHC(ILDZR)+SYSMHC
      WLBHRS=(SMCBL+SMCML)/WLBH1
CJK
CJK
CJK    WLBHRS=WEIGHTED HOURS FOR BUILDING LANDING AND
CJK    MOVING BETWEEN LANDINGS ** THIS VALUE IS USED
CJK    IN THE LP HOURS COLUMNS BY METHOD
CJK
CJK
      SMCLMM=SMCBL+SMCML
      WRITE(KW,2175)IDL08,WLBHRS,SMCLMM
 2175 FORMAT(4X,I4,103X,F8.2,2X,F9.2)
      LOGMET(3,IDL08)=WLBHRS
 2200 CONTINUE
      WRITE(KW,2250)
 2250 FORMAT(/,2X,127('*'),//)
      WRITE(KW,2300)
 2300 FORMAT(2(/),1X,127('*'),/,49X,'MINIMUM',4X,'MAXIMUM',6X,
     1'FIXED',
     24X,'SKIDDING',3X,'TRAIL',3X,'SLOPE',9X,'AREA',2X,'FIXED',/,
     32X,'METHOD',2X,'LANDING',4X,'AREA',7X,'AREA',5X,'AREA',
     43X,'SKIDDING',3X,'SKIDDING',3X,'SKIDDING',2X,'CORRECTION',
     53X,'TRAVEL LOADED',3X,'DIFFICULTY',2X,'TIME',/,
     62X,'NUMBER',3X,'NUMBER',2X,'NUMBER',5X,'VOLUME',4X,
     7'ACRES',3X,'DISTANCE',3X,'DISTANCE',3X,'DISTANCE',6X,
     8'FACTOR',3X,'DIRECTION (%)',7X,'FACTOR',2X,'CYCLE',/)
 2350 CONTINUE
CJK
CJK
```

```
CJK *************CARD TYPE 13 ***********************************
CJK
CJK
CJK   IMN=METHOD NUMBER, ILN=LANDING NUMBER,IAN=AREA NUMBER,
CJK   AV=AREA VOLUME, AA=AREA ACRES, AN=MINIMUM SKIDDING
CJK   DISTANCE, AX=MAXIMUM SKIDDING DISTANCE, AF=FIXED SKIDDING
CJK   IN AREA WHERE AN AND AX WOULD APPLY; AC=CORRECTION FACTOR
CJK   CONVERTING STRAIGHT LINE SKIDDING DISTANCE TO ACTUAL
CJK   DISTANCE TRAVELED BY SKIDDER; AS=SLOPE OF SKID TRAIL IN
CJK   PERCENT IN DIRECTION OF TRAVEL LOADED; AD=AREA DIFFICULTY
CJK   CODE AFFECTING SKIDDING TIME SIMILAR TO SKIDDER EFFICIENCY
CJK   (IE 0.80)
CJK
CJK
 2375 CONTINUE
      READ(KR,2400)IMN,ILN,IAN,AV,AA,AN,AX,AF,AC,AS,AD,AT
 2400 FORMAT(I1,I2,I2,F9.0,F6.0,F8.0,
     1F8.0,F8.0,1X,F5.2,F5.0,1X,F4.2,1X,F4.1)
      IF(IMN.EQ.0)GO TO 2500
      AREAV(IMN,ILN,IAN)=AV
      AREAA(IMN,ILN,IAN)=AA
      AREAMN(IMN,ILN,IAN)=AN
      AREAMX(IMN,ILN,IAN)=AX
      AREAFD(IMN,ILN,IAN)=AF
      AREACF(IMN,ILN,IAN)=AC
      AREATS(IMN,ILN,IAN)=AS
      AREADI(IMN,ILN,IAN)=AD
      AREAFT(IMN,ILN,IAN)=AT
      WRITE(KW,2450)IMN,ILN,IAN,AV,AA,AN,AX,AF,AC,AS,AD,AT
 2450 FORMAT(4X,I4,5X,I4,4X,I4,1X,F10.0,2X,F7.0,2X,F9.0,
     12X,F9.0,2X,F9.0,5X,F7.2,10X,F6.0,6X,F7.2,1X,F6.1)
      GO TO 2350
 2500 CONTINUE
      WRITE(KW,2250)
      WRITE(KW,2550)
 2550 FORMAT(1H1,/,2X,126('*'),/,75X,11('*'),1X,'ALL'
     1,1X,'SKIDDERS WORKING TOGETHER',1X,11('*'),/,68X,
     2'AREA',/,28X,'MINIMUM',3X,'MAXIMUM',4X,'CYCLE',2X,
     3'NUMBER',6X,'SKID',10X,'AREA',4X,'LANDING ',2X,
     4'LANDING',5X,'METHOD',6X,'METHOD',/,2X,
     5'METHOD',2X,'LAND',2X,'AREA',2X,'SKID',3X,'VOLUME',
     64X,'VOLUME',5X,'TIME',6X,'OF',6X,'TIME',6X,
     7'SKIDDING',3X,'SKIDDING',2X,'SKIDDING',3X,'SKIDDING',
     84X,'SKIDDING')
      WRITE(KW,2600)
 2600 FORMAT(6X,'NO',4X,'NO',4X,'NO',4X,'NO',2X,
     1'SKIDDED',3X,'SKIDDED',2X,'MINUTES',2X,'CYCLES',
     25X,'HOURS',9X,'HOURS',7X,'HOURS',5X,'COSTS',6X,
     3'HOURS',7X,'COSTS',/)
CJK
CJK
CJK       START OF DO LOOP FOR METHODS++++SKIDDING TIMES
CJK
CJK
CJK  SKIDDING AVERAGE VALUES FROM TVA TECHNICAL NOTE B18, 1976
CJK  BY JERRY KOGER "FACTORS AFFECTING THE PRODUCTION OF
CJK  RUBBER TIRED SKIDDERS" TVA, NORRIS, TN  37828
CJK  RADCUR = RADIUS OF CURVATURE AVERAGE VALUE OF 483.99 FT
CJK  RUTD=RUT DEPTH ON SKID TRAIL; VALUE OF 2" ASSUMED
CJK  CONEP=SOIL STRENGTH BY CONE PENETROMETER, ASSUMED 200
CJK  ARCLG= ARC LENGTH OF SKID TRAIL, USED AVERAGE OF 132.
CJK  SEE TVA TECHNOTE B18 PAGE 23 FOR THESE VALUES
CJK
      RADCUR=483.99
      RUTD=6.3
      CONEP=192.2
      ARCLG=131.6
      ELEV=1547.1
      DO 3100 IDL10=1,NMETH
      SMVOLM=0.0
      SMAVLM=0.0
      SMHA=0.0
      [illegible]=0.0
      SFSKD=0.0
      SWSKD=0.0
      IDLB04=ILAND(IDL10)
CJK
CJK
CJK      START OF DO LOOP FOR LANDINGS++++++ SKIDDING TIMES
CJK
CJK
      DO 3000 IDL11=1,IDLB04
      SMHA=0.0
      SMAA=0.0
      SMAV=0.0
      ASKDPL=0.0
      FSKDPL=0.0
      WSKDPL=0.0
      AMAXN=0.0
      IDLB05=JNAREA(IDL10,IDL11)
CJK
CJK
CJK     START OF DO LOOP FOR AREA+++++SKIDDING TIMES
CJK
CJK
      DO 2900 IDL12=1,IDLB05
      IF(AREAV(IDL10,IDL11,IDL12).EQ.0.0)GO TO 2900
      SMHA=0.0
      AMAXN=AMAXN+1.0
      SMAV=SMAV+AREAV(IDL10,IDL11,IDL12)
      SMAA=SMAA+AREAA(IDL10,IDL11,IDL12)
      ASKDPL=ASKDPL+0.5*(AREAMN(IDL10,IDL11,IDL12)+
     1AREAMX(IDL10,IDL11,IDL12))
      FSKDPL=FSKDPL+AREAFD(IDL10,IDL11,IDL12)
      WSKDPL=WSKDPL+(((0.5*(AREAMN(IDL10,IDL11,IDL12)+
     1AREAMX(IDL10,IDL11,IDL12)))*AREACF(IDL10,IDL11,IDL12))+
     2AREAFD(IDL10,IDL11,IDL12))*AREAV(IDL10,IDL11,IDL12)
CJK
CJK
CJK    START OF DO LOOP FOR SKIDDERS++++SKIDDING TIMES
CJK
CJK
      DO 2800 IDL13=1,NSKD
CJK
CJK
CJK   ************** CARD TYPE 15 ***************************
CJK
CJK
CJK   KM=MEHTOD NUMBER; KL=LANDING NUMBER;KA=AREA NUMBER;
CJK   KS=SKIDDER NUMBER; SKVMN=MINIMUM VOLUME SKIDDED PER CYCLE;
CJK   SKVMS=MAXIMUM VOLUME SKIDDED PER CYCLE;
CJK   IF SKVMN=SKVMX THEN INTEGRATION
CJK   EQUATION FOR SKIDDING TIME IS NOT USED
CJK
CJK
CJK
      READ(KR,2700)KM,KL,KA,KS,SKVMN,SKVMX
 2700 FORMAT(I1,1X,I2,1X,I2,1X,I2,F10.1,F10.1)
      XN=AREAMN(KM,KL,KA)
      XX=AREAMX(KM,KL,KA)
      FX=AREAFD(KM,KL,KA)
      FC=AREACF(KM,KL,KA)
CJK
CJK
CJK    CODE SYMBOLS USED FAC=FACTOR; A...=SYMBOL IN APPENDIX
CJK     OF THIS REPORT FOR SKIDDING EQUATION; E=SYMBOL FOR
CJK    TRAVEL EMPTY .........THIS APPLIES TO FACAE,FACBE
CJK    TYPE CODEING USED BELOW
CJK
      IF(XN.EQ.XX)FACAE=(FX+(XN*FC))**1.022449
CJK
CJK
CJK   IF XN.NE.XX THEN INTEGRATION EQUATION IS USED TO COMPUTE
CJK   VALUE OF FACAE  ++TRAVEL EMPTY
CJK
CJK
      IF(XN.NE.XX)FACAE=(FX**1.022449)+((1.0/(XX*FC-XN*FC))*
     1(((XX*FC)**2.022449/2.022449)-((XN*FC)**2.022449/2.022449)))
      FACBE=RADCUR**3.549048
      FACCE=(SKDHP(IDL13))**1.317563
      FACCE=120.0**1.317563
      FACDE=(1.0+RUTD)**0.223969
CJK   FACEE=(AREAE(KM,KL,KA))**0.180727
      FACEE=ELEV**0.180727
      TS=ATAN(AREATS(KM,KL,KA)/100.0)*CTDEG
      FACFE=(1.0+SIN(TS*CTRAD))**2.156775
      FACHE=CONEP**0.183381
      FACIE=ARCLG**6.943695
      IF(IUNIT.EQ.1)VSN=SKVMN*CONPTB
      IF(IUNIT.EQ.1)VSX=SKVMX*CONPTB
      IF(IUNIT.EQ.2)VSN=SKVMN*CONBTB
      IF(IUNIT.EQ.2)VSX=SKVMX*CONBTB
      IF(IUNIT.EQ.3)VSN=SKVMN*CONCTB
      IF(IUNIT.EQ.3)VSX=SKVMX*CONCTB
      IF(IUNIT.EQ.4)VSN=SKVMN*CONUTB
      IF(IUNIT.EQ.4)VSX=SKVMX*CONUTB
      IF(SKVMN.EQ.SKVMX)FACJL=VSN**0.110305
CJK
CJK
CJK    IF SKVMN.NE.SKVMX THEN INTEGRATION EQUATION IS USED
CJK    TO COMPUTE VALUE OF FACJL  *** VOLUME FACTOR FOR
CJK    TRAVEL LOADED
CJK
CJK
      IF(SKVMN.NE.SKVMX)FACJL=((1.0/(VSX-VSN))*
     1((VSX**1.110305)/1.110305)*
     2((VSN**1.110305)/1.110305))
      IF(XN.EQ.XX)FACAL=(FX+(XN*FC))**1.1098034
CJK
CJK
CJK    IF XN.NE.XX THEN INTEGRATION EQUATION IS USED TO COMPUTE
CJK    VALUE OF FACAL+++ DISTANCE FACTOR--TRAVEL LOADED
CJK
CJK
      IF(XN.NE.XX)FACAL=(FX**1.1098034)+((1.0/(XX*FC-XN*FC))*
     1(((XX*FC)**2.1098034/2.1098034)-((XN*FC)**2.1098034
     22/2.1098034)))
      FACBL=RADCUR**3.472234
      FACDL=(1.0+RUTD)**0.116935
C     FACEL=(AREAE(KM,KL,KA))**0.098604
      FACEL=ELEV**0.098604
      FACFL=(1.0+SIN(TS*CTRAD))**0.681159
      FACGL=(SKDWT(IDL13))**3.234567
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75900        FACHL=CONEP**0.067053
76000        FACCL=(SKDHP(IDL13))**3.157504
76100        FACIL=ARCLG**7.456998
76200        TIMEE=0.3395469*((FACAE*FACBE*FACCE*FACDE*FACEE*FACFE)/
76300       1(FACHE*FACIE))
76400        TIMEL=0.00005166*((FACJL*FACAL*FACBL*FACDL*FACEL*
76500       1FACFL*FACGL)/(FACHL*FACCL*FACIL))
76600 CJK
76700 CJK
76800 CJK    T=SKIDDING CYCLE TIME IN MINUTES AS COMPUTED BY EQUATION
76900 CJK    2 PAGE 31 OF TVA TECHNICAL NOTE 818, 1976 BY JERRY KOGER
77000 CJK    "FACTORS AFFECTING THE PRODUCTION OF RUBBER TIRED SKIDDERS"
77100 CJK     TVA, NORRIS, TN, 37828
77200 CJK
77300 CJK     TIMEE=TRAVEL TIME EMPTY; TIMEL=TRAVEL TIME LOADED;
77400 CJK     AREAFT()=FIXED CYCLE TIME; SKEF=SKIDDER EFFICIENCY;
77500 CJK     AREADI(,) =AREA DIFFICULTY FACTOR FOR SKIDDING
77600 CJK
77700 CJK
77800        T=((TIMEE+TIMEL+AREAFT(KM,KL,KA))/SKDEF(KS))/AREADI(KM,KL,KA)
77900        SKSFE=(FACBE*FACCE*FACDE*FACEE)/(FACHE*FACIE)
78000        SKSFL=(FACBL*FACDL*FACEL)/(FACHL*FACIL)
78100        CYCLEN=(AREAV(KM,KL,KA))/((SKVMN+SKVMX)/2.0)
78200        ATH=(T*CYCLEN)/60.0
78300        WRITE(KW,2750)KM,KL,KA,KS,SKVMN,SKVMX,T,CYCLEN,ATH
78400  2750 FORMAT(4X,I4,2X,I4,2X,I4,2X,I4,F9.1,1X,F9.1,1X,
78500       1F8.2,1X,F7.0,F10.2)
78600        SMHA=SMHA+(1.0/ATH)
78700  2800 CONTINUE
78800 CJK
78900 CJK
79000 CJK     SMHAA= THE TIME IT WOULD TAKE ALL SKIDDERS IF THEY
79100 CJK     WORKED TOGETHER ON THIS AREA
79200 CJK
79300 CJK
79400        SMHAA=1.0/SMHA
79500        SMHLA=SMHLA+SMHAA
79600        IF(NSKD.GT.1)WRITE(KW,2850)KM,KL,KA,SMHAA
79700  2850 FORMAT(4X,I4,2X,I4,2X,I4,57X,F10.2)
79800  2900 CONTINUE
79900        VOLML(IDL10,IDL11)=SMAV
80000        VOLMA(IDL10,IDL11)=SMAA
80100        ASKDBL(IDL10,IDL11)=ASKDPL/AMAXN
80200        FSKDBL(IDL10,IDL11)=FSKDPL/AMAXN
80300        SWSKD=SWSKD+WSKDPL
80400        WSKDBL(IDL10,IDL11)=WSKDPL/SMAV
80500        SASKD=SASKD+ASKDBL(IDL10,IDL11)
80600        SFSKD=SFSKD+FSKDBL(IDL10,IDL11)
80700        SMHMA=SMHMA+SMHLA
80800        SKDLC=SMHLA*SMSKHC
80900        SMVOLM=SMVOLM+SMAV
81000        SMACLM=SMACLM+SMAA
81100        WRITE(KW,2950)KM,KL,SMHLA,SKDLC
81200  2950 FORMAT(4X,I4,2X,I4,73X,F10.2,F10.2)
81300  3000 CONTINUE
81400        VOLBM(IDL10)=SMVOLM
81500        ACRBM(IDL10)=SMACLM
81600        SKDMC=SMHMA*SMSKHC
81700        LOGMET(4,IDL10)=SMHMA
81800        ADL11=IDLB04
81900        ASKDBM(IDL10)=SASKD/ADL11
82000        FSKDBM(IDL10)=SFSKD/ADL11
82100        WSKDBM(IDL10)=SWSKD/SMVOLM
82200        WRITE(KW,3050)KM,SMHMA,SKDMC
82300  3050 FORMAT(4X,I4,99X,F11.2,1X,F11.2,//)
82400  3100 CONTINUE
82500        WRITE(KW,3125)
82600  3125 FORMAT(/,2X,126('*'))
82700        WRITE(KW,3150)
82800  3150 FORMAT(1H1,2(/),125('*'),/,62X,8('*'),' PER LANDING',1X,
82900       19('*'),5X,9('*'),' PER METHOD',1X,9('*'),/,
83000       284X,'WEIGHTED',27X,'WEIGHTED',/,74X,'AVERAGE',4X,'AVERAGE',
83100       317X,'AVERAGE ',3X,'AVERAGE',/,63X,'AVERAGE',6X,'FIXED',5X,
83200       4'TRAVEL',6X,'AVERAGE',6X,'FIXED',5X,'TRAVEL',/,2X,
83300       5'METHOD',2X,'LANDING',3X,'LANDING',3X,'LANDING',5X,
83400       6'METHOD',5X,'METHOD',3X,'SKIDDING',3X,'SKIDDING',3X,
83500       7'SKIDDING',5X,'SKIDDING',3X,'SKIDDING',3X,'SKIDDING',/,
83600       82X,'NUMBER',3X,'NUMBER',4X,'VOLUME',5X,'ACRES',5X,'VOLUME',
83700       96X,'ACRES',3X,'DISTANCE',3X,'DISTANCE',3X,'DISTANCE',
83800       15X,'DISTANCE',3X,'DISTANCE',3X,'DISTANCE',/)
83900        DO 3250 IDL14=1,NMETH
84000        IDLB5A=ILAND(IDL14)
84100        DO 3230 IDL14A=1,IDLB5A
84200 CJK
84300 CJK
84400 CJK     OUTPUT LANDING AND METHOD VOLUMES AND SKIDDING INFO
84500 CJK     BY LANDING ONLY
84600 CJK
84700 CJK
84800        WRITE(KW,3220)IDL14,IDL14A,VOLML(IDL14,IDL14A),
84900       1VOLMA(IDL14,IDL14A),ASKDBL(IDL14,IDL14A),
85000       2FSKDBL(IDL14,IDL14A),WSKDBL(IDL14,IDL14A)
85100  3220 FORMAT(4X,I4,5X,I4,1X,F9.0,2X,F8.0,25X,F8.0,3X,F8.0,3X,F8.0)
85200  3230 CONTINUE
85300 CJK
85400 CJK
85500 CJK     OUTPUT LANDING AND METHOD VOLUME, ACRES AND SKIDDING
85600 CJK     DISTANCES BY METHOD ONLY
85700 CJK
85800 CJK
85900        WRITE(KW,3240)IDL14,VOLBM(IDL14),ACRBM(IDL14),
86000       1ASKDBM(IDL14),FSKDBM(IDL14),WSKDBM(IDL14)
86100  3240 FORMAT(4X,I4,30X,F10.0,1X,F10.0,37X,F9.0,2X,F9.0,2X,F9.0)
86200  3250 CONTINUE
86300        WRITE(KW,3300)
86400  3300 FORMAT(/,2X,125('*'))
86500        WRITE(KW,3350)
86600  3350 FORMAT(2(/),2X,27('*'),/,24X,'TRUCK',/,
86700       123X,'TRAVEL',/,2X,'METHOD',2X,'LANDING',2X,
86800       2'CORRECTION',/,2X,'NUMBER',3X,'NUMBER',6X,'FACTOR',/)
86900        DO 3500 IDL15=1,NMETH
87000        IDLB06=ILAND(IDL15)
87100        DO 3400 IDL16=1,IDLB06
87200 CJK
87300 CJK ************** CARD TYPE 16 **********************
87400 CJK
87500 CJK
87600 CJK     ITMN=METHOD NUMBER; ITLN=LANDING NUMBER FOR THIS METHOD
87700 CJK     TKTVCF=TRUCK SPEED CORRECTION FACTOR THAT RECOGNIZES
87800 CJK     THAT TRAVEL SPEED MAY DECREASE AS THE ROAD STANDARD
87900 CJK     DECREASES AS A FUNCTION OF ROAD LENGTH
88000 CJK     (IE 0.80 WOULD MEAN THAT TRAVEL SPEED AT THE END
88100 CJK     WAS 80 % OF BEGINNIG TRAVEL SPEED)
88200 CJK
88300 CJK
88400        READ(KR,3360)ITMN,ITLN,TKTVCF
88500  3360 FORMAT(I1,1X,I2,1X,F4.2)
88600        TKTOF(IDL15,IDL16)=TKTVCF
88700        WRITE(KW,3370)ITMN,ITLN,TKTVCF
88800  3370 FORMAT(4X,I4,5X,I4,6X,F6.2)
88900  3400 CONTINUE
89000  3500 CONTINUE
89100        WRITE(KW,3550)
89200  3550 FORMAT(/,2X,27('*'),//)
89300        WRITE(KW,3600)
89400  3600 FORMAT(1H1,/,2X,94('*'),/,57X,5('*'),1X,'ALL TRUCKS',1X,
89500       1'WORKING TOGETHER',1X,5('*'),/,
89600       228X,'CYCLE',4X,'NUMBER',5X,'TRUCK',5X,'LANDING',
89700       33X,'LANDING',5X,'METHOD',5X,'METHOD'/,
89800       42X,'METHOD',2X,'LANDING',3X,'TRUCK',4X,'TIME',8X,
89900       5'OF',6X,'TIME',4X,'TRUCKING',2X,'TRUCKING',3X,
90000       6'TRUCKING',3X,'TRUCKING',/,
90100       72X,'NUMBER',3X,'NUMBER',2X,'NUMBER',3X,'HOURS',5X,
90200       8'LOADS',5X,'HOURS',7X,'HOURS',6X,'COST',
90300       96X,'HOURS',7X,'COST',/)
90400 CJK
90500 CJK
90600 CJK    START OF DO LOOP FOR METHODS++++TRUCKING TIMES
90700 CJK
90800 CJK
90900        DO 3950 IDL16=1,NMETH
91000        SMTKMH=0.0
91100        IDLB07=ILAND(IDL16)
91200 CJK
91300 CJK
91400 CJK    START OF DO LOOP FOR LANDINGS++++TRUCKING TIMES
91500 CJK
91600 CJK
91700        DO 3850 IDL17=1,IDLB07
91800        SMTKLH=0.0
91900        SMTKH=0.0
92000        DO 3750 IDL18=1,NTRK
92100 CJK
92200 CJK
92300 CJK    START OF DO LOOP FOR TRUCKS+++TRUCKING TIMES
92400 CJK
92500 CJK
92600        TKTEWM=DFTBTM/TKTENW(IDL18)
92700        TKTLWM=DFTBTM/TKTLNW(IDL18)
92800        TKTEBR=(DSFTB(IDL16,IDL17)/5280.0)/
92900       1((TKTEWD(IDL18)*(1.0+TKTOF(IDL16,IDL17)))/2.0)
93000        TKTLBR=(DSFTB(IDL16,IDL17)/5280.0)/
93100       1((TKTLWD(IDL18)*(1.0+TKTOF(IDL16,IDL17)))/2.0)
93200 CJK
93300 CJK
93400 CJK      TKCT=TRUCK CYCLE TIME; TKTEWM=TRAEMPTY TIME
93500 CJK       OVER NON-WOODS ROAD;  TKTLWM=TRAVEL LOADED TIME
93600 CJK       OVER NON-WOODS ROAD;  TKTEBR=TRAVEL TIME EMPTY
93700 CJK       OVER WOODS OR BUILT ROAD; TKTLBR=TRAVEL TIME
93800 CJK       LOADED OVER BUILT OR WOODS ROAD
93900 CJK
94000 CJK
94100        TKCT=(TKTEWM+TKTLWM+TKTEBR+TKTLBR+(TKFTPC(IDL18)/60.0))
94200       1/TKEF(IDL18)
94300        TKCYC=VOLML(IDL16,IDL17)/TKVOL(IDL18)
94400        TKH=TKCT*TKCYC
94500        SMTKH=SMTKH+(1.0/TKH)
94600        WRITE(KW,3700)IDL16,IDL17,IDL18,TKCT,TKCYC,TKH
94700  3700 FORMAT(4X,I4,5X,I4,4X,I4,1X,F7.2,1X,F9.1,F10.2)
94800  3750 CONTINUE
94900 CJK
95000 CJK
95100 CJK     SMTKHL=THE TIME IT WOULD TAKE IF ALL TRUCKS WORKED
95200 CJK     TOGETHER
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```
CJK
CJK
      SMTKHL=1.0/SMTKH
      SMTKLH=SMTKLH+SMTKHL
      SMTKLC=SMTKLH*SMTKHC
      SMTKMH=SMTKMH+SMTKLH
      IF(NTRK.GT.1)WRITE(KW,3800)IDL16,IDL17,SMTKLH,SMTKLC
 3800 FORMAT(4X,I4,5X,I4,38X,F10.2,F9.2)
 3850 CONTINUE
      SMTKMC=SMTKMH*SMTKHC
      LOGMET(5,IDL16)=SMTKMH
      WRITE(KW,3900)IDL16,SMTKMH,SMTKMC
 3900 FORMAT(4X,I4,67X,F11.2,F11.2,/)
 3950 CONTINUE
      WRITE(KW,4000)
 4000 FORMAT(/,2X,94('*'))
       IF(ICTRAT.EQ.0)GO TO 4500
       WRITE(KW,4250)
 4250 FORMAT(2(/),2X,21('*'),/,
     12X,'CONSTRAINT',/,8X,'CODE',/,2X,'1= ROAD HR',/,
     22X,'2= LAND HR',6X,'UPPER',/,2X,'3= SKID HR',6X,'BOUND',/,
     32X,'4= TRUK HR',6X,'VALUE',/)
       DO 4400 IDL23=1,ICTRAT
      K=IDL23+7
      JCONSC=NMETH+ICTRAT+12
CJK
CJK
CJK  *********** CARD TYPE 17 ******************************
CJK
CJK
CJK       ICSTFO=CONSTRAINT CODE, CSTVAL VALUE OF THIS
CJK       CONSTRAINT
CJK
CJK
      READ(KR,4300)ICSTFO,CSTVAL
 4300 FORMAT(I1,1X,F9.1)
      MCONSC=JCONSC-(4-ICSTFO)
CJK
CJK UPPER BOUND ROAD CONSTRUCTION HOURS
CJK
      IF(ICSTFO.EQ.1)P(K)=CSTVAL
      IF(ICSTFO.EQ.1)A(K,MCONSC)=1.0
      IF(ICSTFO.EQ.1)JVAR(K)=1
CJK
CJK UPPER BOUND FOR WEIGHTED LANDING CONST. & MOVING
CJK
      IF(ICSTFO.EQ.2)P(K)=CSTVAL
       IF(ICSTFO.EQ.2)A(K,MCONSC)=1.0
       IF(ICSTFO.EQ.2)JVAR(K)=2
CJK
CJK UPPER BOUND FOR SKIDDING HOURS
CJK
       IF(ICSTFO.EQ.3)P(K)=CSTVAL
       IF(ICSTFO.EQ.3)A(K,MCONSC)=1.0
       IF(ICSTFO.EQ.3)JVAR(K)=3
CJK
CJK  UPPER BOUND FOR TRUCKING HOURS
CJK
       IF(ICSTFO.EQ.4)P(K)=CSTVAL
       IF(ICSTFO.EQ.4)A(K,MCONSC)=1.0
       IF(ICSTFO.EQ.4)JVAR(K)=4
       WRITE(KW,4350)ICSTFO,CSTVAL
 4350 FORMAT(6X,I2,7X,F8.0)
 4400 CONTINUE
      WRITE(KW,4450)
 4450 FORMAT(/,2X,21('*'),/)
 4500 CONTINUE
       IF(IUNIT.EQ.1)TOTLVL=HARVOL/2000.0
       IF(IUNIT.EQ.2)TOTLVL=HARVOL/1000.0
       IF(IUNIT.EQ.3)TOTLVL=HARVOL/100.0
       IF(IUNIT.EQ.4)TOTLVL=HARVOL/1.0
       WRITE(KW,4700)
 4700 FORMAT(1H1,/,64X,'METHOD SUMMARY',/,1X,127('*'),/,31X,
     1'LANDING CONSTRUCTION',58X,'TOTAL',6X,
     2'METHOD',/,9X,'ROAD CONSTRUCTION',5X,'AND',2X,'SYSTEM',
     33X,'MOVING',10X,'SKIDDING',15X,'TRUCKING',16X,'METHOD',
     42X,'HARVESTING',/,1X,'METH',2X,21('-'),3X,21('-'),3X,
     521('-'),3X,21('-'),4X,'HARVESTING',8X,'UNIT',/,
     63X,'NO',2X,'HOURS',6X,'$$$',2X,'$/VOL',3X,'HOURS',6X,
     7'$$$',2X,'$/VOL',3X,'HOURS',6X,'$$$',2X,'$/VOL',3X,
     8'HOURS',6X,'$$$',2X,'$/VOL',9X,'COSTS',7X,'COSTS',/)
      DO 4900 IDL30=1,NMETH
      SOUT01=LOGMET(2,IDL30)*SMDZHC
      SOUT02=SOUT01/TOTLVL
      SOUT03=LOGMET(3,IDL30)*(DZRHC(ILDZR)+SYSMHC)
      SOUT04=SOUT03/TOTLVL
      SOUT05=LOGMET(4,IDL30)*SMSKHC
      SOUT06=SOUT05/TOTLVL
      SOUT07=LOGMET(5,IDL30)*SMTKHC
      SOUT08=SOUT07/TOTLVL
      SOUT09=SOUT01+SOUT03+SOUT05+SOUT07
      SOUT10=SOUT09/TOTLVL
      WRITE(KW,4800)IDL30,LOGMET(2,IDL30),SOUT01,SOUT02,
     1LOGMET(3,IDL30),SOUT03,SOUT04,LOGMET(4,IDL30),
     2SOUT05,SOUT06,LOGMET(5,IDL30),SOUT07,SOUT08,
     3SOUT09,SOUT10
 4800 FORMAT(2X,I3,1X,F6.0,1X,F8.0,1X,F6.0,2X,F6.0,1X,
     1F8.0,F7.0,2X,F6.0,1X,F8.0,1X,F6.0,2X,F6.0,1X,
     2F8.0,1X,F6.0,2X,F12.2,2X,F10.2)
 4900 CONTINUE
      WRITE(KW,5000)
 5000 FORMAT(/,127('*'))
CJK
CJK
CJK     ############### SECTION 2 ###########################
CJK
CJK
CWC
CWC  FORMAT STATEMENTS USED IN RAVINDRIN'S PROGRAM
CWC
    1 FORMAT(1H1,/,3X,'ITERATION NO=',I5)
C 112 FORMAT(1X,12X,4I12/(13X,4I12)/(13X,4I12)/(13X,2I12))
C 121 FORMAT(1X,I2,F8.2,3X,4F12.2/(14X,4F12.2)/(14X,4F12.2)/
C    2(14X,2F12.2))
C 122 FORMAT(5X,4F13.1/(5X,3F13.1))
C 123 FORMAT(1X,F12.1,1X,4F12.1/(4X,4F12.1)/(4X,4F12.1)/(
C    34X,2F12.1))
C 325 FORMAT( 1X/ 7X,8HSOLUTION,10X,7HTABLEAU)
C 326 FORMAT( 1X,14HVARIABLE COSTS,2X,3F15.4/(2X,4F15.4)/(2X
C    4,4F15.4)/(2X,3F15.4))
  102 FORMAT(1X,5X,37HTHE OBJECTIVE FUNCTION IS NOT BOUNDED)
  335 FORMAT(1HA)
      IP1 = 1
      IP2 = 1
CWC
CWC  M = NUMBER OF COLUMNS IN BASIS
CWC  N = NUMBER OF COLUMNS IN "A" MATRIX
CWC
      M = ICTRAT+7
      M2 = NMETH+10
      N = NMETH+5+M
      N2 = NMETH+5
      M3 = M+1
      N9 = NMETH+M
CWC
CWC  IREP = 0 IF ONLY FIRST TABLEAU IS TO BE PRINTED
CWC       - 1 IF ALL TABLEAUS SHOULD BE PRINTED
CWC
      IREP = 1
      IT=0
      WRITE(KW,335)
      EP=.5E-6
CWC
CWC  "JVAR" ARRAY CONTAINS A NUMBER CORRESPONDING TO EACH COLUMN
CWC  IN THE "A" MATRIX.  DUE TO THE METHOD OF INPUT INTO THE
CWC  MATRIX, THE FIRST M COLUMNS (BASIS) OF THE MATRIX MUST
CWC  BE NUMBERED TO REFLECT THE FACT THAT IT SHOULD APPEAR
CWC  AT THE END OF THE MATRIX.
CWC
      DO 3 I=1,M
      JVAR(I) = N2+I
    3 CONTINUE
CWC
CWC  NUMBER OTHER COLUMNS AS THOUGH THEY WERE AT FRONT OF MATRIX
CWC
      DO 4 I=M3,N
      JVAR(I)=I-M
    4 CONTINUE
      K=M3
CWC
CWC  SET PRODUCT PRICE IN OBJECTIVE FUNCTION
CWC
      C(K) = PRODPC
      K = NMETH+M3+1
CWC
CWC  SET ROAD EQUIPMENT HOURLY COST IN OBJECTIVE FUNCTION
CWC
      C(K) = -SMDZHC
      K = K+1
CWC
CWC  SET LANDING CONSTRUCTION HOURLY COST IN OBJECTIVE FUNCTION
CWC  LANDING CONSTRUCTION HOURLY COST = ROAD EQUIPMENT HOURLY
CWC     COST + SYSTEM MOVE HOURLY COST
CWC
      C(K) = -DZRHC(ILDZR)-SYSMHC
      K = K+1
CJK
CJK
CJK  SMSKHC= SUM OF HOURLY SKIDDER COSTS
CJK  SMTKHC= SUM OF HOURLY TRUCKING COSTS
CJK
CJK
      C(K) = -SMSKHC
      K = K+1
      C(K) = -SMTKHC
      K = K+1
CWC
CWC  SET RIGHT HAND CONSTANTS OF FIRST FIVE EQUATIONS
CWC  EQUAL TO 0.0
CWC
      DO 778 I=1,5
      P(I) = 0.0
      B(I) = 0.0
  778 CONTINUE
      A(1,M3)=1.0
      K9=M+NMETH+1
      K8=M+2
OWC
OWC  STORE DATA IN "LOGMET" MATRIX IN "A" MATRIX TO BE USED
OWC  IN LP
OWC
      DO 317 I=K8,K9
      DO 242 J=1,M
      K=I-M-1
      A(J,I) = LOGMET(J,K)
  242 CONTINUE
  317 CONTINUE
OWC
OWC  STORE Z VALUES INTO "A" MATRIX
OWC
      K9 = K9+1
      K8 = K9+3
      J=1
      DO 467 I=K9,K8
      J=J+1
      A(J,I)=-1.0
  467 CONTINUE
OWC
OWC  STORE CONSTRAINT RELATING TO TRACK VOLUME INTO "A" MATRIX
OWC
      A(6,M3)=1.0
OWC
OWC  STORE TRACK VOLUME INTO "B" MATRIX
OWC
      P(6)=TOTLVL
      B(6)=TOTLVL
      M4 = M3+1
OWC
OWC  STORE CONSTRAINT RESTRICTING SUM OF METHODS TO EQUAL ONE
OWC
      DO 992 K=1,NMETH
      A(7,M4) = 1.0
      M4 = M4+1
  992 CONTINUE
OWC
OWC  STORE 1.0 INTO "B" MATRIX
OWC
      P(7) = 1.0
      B(7) = 1.0
      DO 5 J=1,N
      JJ=JVAR(J)
    5 CC(JJ)=C(J)
      L=M+1
      DO 301 I=1,N
      CI(I)=C(I)
      IVAR(I)=JVAR(I)
  301 CONTINUE
OWC
OWC  STORE BASIS INTO MATRIX
OWC
      DO 444 I=1,M
      A(I,I)=1.0
  444 CONTINUE
  194 CMZM=-9.E30
OWC
OWC  CALCULATE C-BAR ROW
OWC  OUTER DO LOOP CONTROLS COLUMNS IN "A" MATRIX
OWC  INNER DO LOOP CONTROLS SUMMING OF EACH ELEMENT OF COLUMN
OWC
      DO 74 JVC=1,N
      Z=0.0
OWC  "Z" IS PRODUCT OF "A" ARRAY COLUMN TIMES CB ELEMENTS OF MATRIX
OWC
      DO 75 I=1,M
   75 Z=Z+A(I,JVC)*CI(I)
OWC
OWC  ENT IS C-BAR ELEMENT FOR THAT COLUMN
OWC  CMZ IS ARRAY THAT HOLDS C-BAR ELEMENTS
OWC
      ENT=C(JVC)-Z
      CMZ(JVC)=ENT
OWC
OWC  FIND LARGEST VALUE IN C-BAR ROW TO USE AS PIVOT COLUMN
OWC  STORE VALUE OF LARGEST C-BAR ELEMENT IN CMZM AND STORE
OWC  PIVOT COLUMN NUMBER IN KOUT
OWC
      IF(CMZM.GT.ENT)GO TO 74
      CMZM=ENT
      KOUT=JVC
   74 CONTINUE
OWC
OWC  INCREMENT ITERATION COUNTER AND WRITE ITERATION MESSAGE
OWC
      IT=IT+1
      WRITE(KW,1)IT
      IF(IREP.EQ.0)GO TO 25
OWC
OWC  CALCULATE Z VALUE AND STORE IN VARIABLE "VALUE"
OWC
  601 VALUE=0.0
      DO 110 I=1,M
  110 VALUE=VALUE+P(I)*CI(I)
OWC
```

```
OWC  WRITE OUT "A" MATRIX AS INPUTTED INTO LP PROGRAM
OWC
CJK
CJK   DEBUG FORMAT OPTION:::: THIS FORMAT IS HARD TO
CJK   FOLLOW BUT SHOWS THE INPUT MATRIX IN THE FORM
CJK   USED BY RAVANDRINA :: SLACKS AND SURPLUS FIRST
CJK   THEN NORMAL LP VALUES
CJHK
      IF(LPCDE.EQ.1)WRITE(KW,6001)M,N
 6001 FORMAT(25X,'ROWS 1 THRU ',I3,'  AND COLUMNS 1 THRU ',I3,
     1'  IN RAVINDRAN LP MATRIX',/)
      DO 2456 K=1,M
      IF(LPCDE.EQ.1)WRITE(KW,8456) (A(K,JHA),JHA=1,N)
 8456 FORMAT(13F10.2)
 2456 CONTINUE
 2457 CONTINUE
OWC
OWC  WRITE OUT TOP THREE OR FOUR LINES OF TABLEAU WHICH DOES
OWC  NOT VARY BY NUMBER OF METHODS
OWC
      WRITE(KW,6000)
 6000 FORMAT(/,1X,128('*'))
      WRITE(KW,6010)
 6010 FORMAT(1X,'*',4X,'* *',7X,'*',99X,'*',11X,'*')
      K2=NMETH+2
      K2=NMETH+M3+1
      WRITE(KW,6020) C(M3),(C(I),I=K2,N)
 6020 FORMAT(1X,'*',4X,'*  *',2X,'CJ',2X,'*',1X,F8.2,49X,4(1X,F9.2),
     11X,'*',3X,'RIGHT',3X,'*')
      WRITE(KW.6030)
 6030 FORMAT(1X,'*',4X,'* B *',5X,'*',99X,'*',11X,'*')
      WRITE(KW,6040)
 6040 FORMAT(1X,'*',4X,'*  A *',4X,101('*'),3X,'HAND',4X,'*')
      N3 = NMETH-1
OWC
OWC  BRANCH TO STATEMENT NUMBER AND COMPLETE OUTPUT ACCORDING
OWC  TO THE NUMBER OF METHODS
OWC
      GO TO (7000,7010,7020),N3
CJK
CJK
CJK CONTROL GOES TO STATEMENT NUMBER 7000 IF 2 METHODS
CJK CONTROL GOES TO STATEMENT NUMBER 7010 IF 3 MEHTODS
CJK CONTROL GOES TO STATEMENT NUMBER 7020 IF 4 METHODS
CJK
CJK
OWC
OWC  WRITE OUT TABLEAU FOR COMPARISON OF TWO METHODS
OWC
 7000 WRITE(KW,6060)
 6060 FORMAT(1X,'*',5X,'*  S *   *',9X,'* METHOD  * METHOD  *'
     1,29X,'*   $/HR  *   $/HR  *   $/HR  *   $/HR  *',11X,'*')
      WRITE(KW,6070)
 6070 FORMAT(1X,'*',2X,'CB',2X,'*',2X,'I *  *  (YO)   *',4X,'1',4X,
     1'*',4X,'2',4X,'*',29X,'*  ROADS  *   LAND  *   SKID  *',
     2'  TRUCK  * CONSTANTS *')
      WRITE(KW,6080)
 6080 FORMAT(1X,'*',7X,'*  S * *',9X,'*  (M1)   *  (M2)   *',29X,
     1'*   (Z1)  *   (Z2)  *   (Z3)  *   (Z4)  *',11X,'*')
      WRITE(KW,6050)
 6050 FORMAT(1X,128('*'))
      WRITE(KW,6115)
 6115 FORMAT(1X,'*',9X,'*',4X,'*',99X,'*',11X,'*')
OWC
OWC  DO LOOP CONTROLS PRINTING OF EACH ROW IN MATRIX
OWC
      DO 8000 I=1,M
      K=IVAR(I)
OWC
OWC  VARIABLES USED TO CONTROL OUTPUT.  YOU HAVE TO THINK
OWC  TO FIGURE OUT THE VALUES THAT NEED TO BE ASSIGNED TO
OWC  THE VARIABLES
OWC
      N5=N9+1
      N6=N5+1
      M4=M3+1
CJK
CJK  OUTPUT FORMAT FOR LP IN CONVEX FORM BY METHOD
CJK  AND HOURS AND NEAT HEADINGS
CJK
      WRITE(KW,6090) C(K),IVAR(I),A(I,M3),(A(I,J),J=M4,N5),(A(I,J),
     1J=N6,N),P(I)
 6090 FORMAT(1X,'*',1X,F7.2,1X,'*',1X,'X',I2,'*',3F10.2,
     129X,4F10.2,'*',1X,F9.2,1X,'*')
 8000 CONTINUE
      WRITE(KW,6115)
      WRITE(KW,6100)
 6100 FORMAT(1X,128('*'))
      WRITE(KW,6110)
 6110 FORMAT(1X,'*',14X,'*',99X,'*',4X,'Z =',4X,'*')
OWC
OWC  WRITE C-BAR ROW OUT IN TABLEAU
OWC
      WRITE(KW,6120) (CMZ(J),J=M3,N),VALUE
 6120 FORMAT(1X,'*',2X,'C-BAR ROW',3X,'*',3F10.2,'*',28X,4F10.2,1X,
     1F11.0,'*')
      GO TO 7040
 7010 WRITE(KW,6130)
OWC
OWC  WRITE OUT TABLEAU FOR COMPARISON OF THREE METHODS
OWC
 6130 FORMAT(1X,'*',5X,'*  S *',3X,'* SELLING ',3('* METHOD  '),'*',
     120X,3('*   $/HR  '),'*',3X,'$/HR',1X,'*',11X,'*')
      WRITE(KW,6140)
 6140 FORMAT(1X,'*',2X,'CB',2X,'*',2X,'I *  * PRICE $ *',4X,'1',4X,
     1'*',4X,'2',4X,'*',4X,'3',4X,'*',20X,'*  ROADS  *   LAND  *',
     2'   SKID  *  TRUCK * CONSTANTS *')
      WRITE(KW,6150)
 6150 FORMAT(1X,'*',7X,'*  S * *   (Y0)  *  (M1)   *  (M2)   *',2X,
     1'(M3)   *',20X,'*',3X,'(Z1)  *   (Z2)  *   (Z3)  *   (Z4) *',
     211X,'*',/,1X,128('*'))
OWC
OWC  DO LOOP CONTROLS PRINTING OF EACH ROW
OWC
      DO 8010 I=1,M
      K = IVAR(I)
OWC
OWC  VARIABLES USED TO CONTROL OUTPUT
OWC
      N5=N9+1
      N6=N5+1
      M4=M3+1
      WRITE(KW,6160) C(K),IVAR(I),A(I,M3),(A(I,J),J=M4,N5),(A(I,J),
     1J=N6,N),P(I)
 6160 FORMAT(1X,'*',1X,F7.2,1X,'*',1X,'X',I2,'*',4F10.2,20X,4F10.2,
     1F10.2,1X,'*')
 8010 CONTINUE
      WRITE(KW,6115)
      WRITE(KW,6100)
      WRITE(KW,6110)
OWC
OWC  PRINTS OUT C-BAR ROW
OWC
      WRITE(KW,6190) (CMZ(J),J=M3,N),VALUE
 6190 FORMAT(1X,'*',2X,'C-BAR ROW',3X,'*',4F10.2,20X,4F10.2,
     1F11.0,'*')
      GO TO 7040
OWC
OWC  WRITE OUT TABLEAU FOR COMPARISON OF FOUR METHODS
OWC
 7020 WRITE(KW,6200)
 6200 FORMAT(1X,'*',5X,'*  S *',3X,'* SELLING ',4('* METHOD  '),'*',
     19X,4('*   $/HR  '),'*',11X,'*')
      WRITE(KW,6210)
 6210 FORMAT(1X,'*',2X,'CB',2X,'*',2X,'I *  * PRICE $ *',4X,'1',4 X,
     1'*',4X,'2',4X,'*',4X,'3',4X,'*',4X,'4',4X,'*',9X,
     2'*  ROADS  *   LAND  *   SKID  *  TRUCK  * CONSTANTS *')
      WRITE(KW,6220)
 6220 FORMAT(1X,'*',7X,'*  S * *   (Y0)  *  (M1)   *  (M2)   *',
     12X,'(M3)   *  (M4)   *',9X,'*   (Z1)  *   (Z2)  *   (Z3)  *',
     23X,'(Z4)  *',11X,'*',/)
      WRITE(KW,6100)
      WRITE(KW,6115)
      DO 8020 I=1,M
OWC
OWC  VARIABLES USED TO CONTROL OUTPUT
OWC
      K = IVAR(I)
      N5 = N9+1
      N6 = N5+1
      M4 = M3+1
      WRITE(KW,6230) C(K),IVAR(I),A(I,M3),(A(I,J),J=M4,N5),(A(I,J),
     1J=N6,N),P(I)
 6230 FORMAT(1X,'*',1X,F7.2,1X,'*',1X,'X',I2,'*',5F10.2,9X,4F10.2,
     1'*',1X,F9.2,1X,'*')
 8020 CONTINUE
      WRITE(KW,6115)
      WRITE(KW,6100)
      WRITE(KW,6110)
OWC
OWC  PRINTS OUT C BAR ROW
OWC
      WRITE(KW,6260) (CMZ(J),J=M3,N),VALUE
 6260 FORMAT(1X,'*',2X,'C-BAR ROW',3X,'*',5F10.2,9X,4F10.2,'*',
     1F11.0,'*')
 7040 CONTINUE
      WRITE(KW,6131)
 6131 FORMAT(1X,128('*'))
OWC
OWC  CHECK FOR OPTIMAL SOLUTION
OWC
      IF(CMZM.LT.EP)GO TO 192
      GO TO 801
   25 IF(IT.EQ.1)GO TO 601
   26 IF(CMZM.LT.EP)GO TO 191
  801 THETA=9.E30
OWC
OWC  DETERMINE PIVOT ELEMENT IN COLUMN.
OWC  DO LOOP CONTROLS SEARCH THROUGH ROWS
OWC
      DO 812 I=1,M
      IF(A(I,KOUT).LE.EP)GO TO 812
      TH=P(I)/A(I,KOUT)
      IF(THETA.LT.TH)GO TO 812
OWC
OWC  VARIABLE THETA CONTAINS VALUE OF PIVOT ELEMENT AFTER DIVISION.
OWC  IRIN CONTAINS THE NUMBER OF THE PIVOT ROW.
OWC
      THETA=TH
      IRIN=I
  812 CONTINUE
OWC
OWC  CHECK FOR UNBOUNDED SOLUTION.  IF FOUND WRITE OUT MESSAGE
OWC  AND END PROGRAM
OWC
      IF(THETA.LT.9.0E20)GO TO 507
      WRITE(KW,102)
      GO TO 192
  191 IF(IREP.EQ.0)GO TO 601
OWC
OWC  VARIABLE PIVOT CONTAINS PIVOT ELEMENT
OWC
  507 PIVOT=A(IRIN,KOUT)
      P(IRIN)=P(IRIN)/PIVOT
OWC
OWC  DIVIDE PIVOT ROW BY PIVOT ELEMENT
OWC
      DO 521 J=1,N
  521 A(IRIN,J)=A(IRIN,J)/PIVOT
OWC
OWC  DO NECESSARY MATRIX DIVISION AFTER PIVOT ELEMENT AND ROW
OWC  IS FOUND.  OUTER LOOP CONTROLS COLUMNS; INNER LOOP
OWC  CONTROLS ROWS
OWC
      DO 522 J=1,N
      IF(J.EQ.KOUT)GO TO 522
      DO 523 I=1,M
      IF(I.EQ.IRIN)GO TO 523
      A(I,J)=A(I,J)-A(I,KOUT)*A(IRIN,J)
  523 CONTINUE
  522 CONTINUE
      DO 529 I=1,M
OWC
OWC  IF STATEMENT PROTECTS PIVOT ELEMENT
OWC
      IF(I.EQ.IRIN)GO TO 529
OWC
OWC  CALCULATE RIGHT-HAND CONSTANTS
OWC
      P(I)=P(I)-P(IRIN)*A(I,KOUT)
OWC
OWC  ZERO OUT PIVOT COLUMN
OWC
      A(I,KOUT)=0.0
  529 CONTINUE
      EP=EP+.5E-6
      CI(IRIN)=C(KOUT)
      IVAR(IRIN)=JVAR(KOUT)
OWC
OWC  SET PIVOT ELEMENT TO 1.0
OWC
      A(IRIN,KOUT)=1.0
      GO TO 194
OWC
OWC  WRITE OUT SUMMARY OF METHODS PICKED FROM LP
OWC
  192 CONTINUE
      I1=0
OWC
OWC  ITOT KEEPS TRACK OF NUMBER OF METHODS PICKED
OWC  TSSUM IS THE SUM OF THE PROPORTION OF EACH METHOD PICKED
OWC
      ITOT=0
      INMIP=0
      TSSUM=0.0
      DO 9431 IHELPM=1,25
 9431 CONTINUE
      DO 9433 IHELPY=1,4
      IARR(IHELPY)=0
      RC(IHELPY)=0.0
      LD(IHELPY)=0.0
      SK(IHELPY)=0.0
      TK(IHELPY)=0.0
 9433 CONTINUE
      SUMRPH=0.0
      SUMRPC=0.0
      SUMLPH=0.0
      SUMLPC=0.0
      SUMSPH=0.0
      SUMSPC=0.0
      SUMTPH=0.0
      SUMTPC=0.0
      SUMTOT=0.0
      WRITE(KW,6500)
 6500 FORMAT(1X,16('*'),57X,'***',40X,12('*'),/,1X,16('*'),
     157X,'***',40X,12('*'),/,1X,16('*'),9X,
     2'ABOVE VALUES IN C-BAR ROW',23X,'***',6X,
     3'ABOVE VALUES IN C-BAR ROW',9X,12('*'),/,1X,16('*'),
     49X,'ARE PENALTY COSTS',31X,'***',6X,
     5'ARE SHADOW PRICES',17X,12('*'),/,1X,16('*'),57X,'***',
     640X,12('*'),/,1X,16('*'),57X,'***',40X,12('*'),
     7/,1X,128('*'))
      WRITE(KW,8042)IT
 8042 FORMAT(1H1,2(/),37X,'AFTER ',I3,' ITERATIONS THE OPTIMUM',
     11X,'SOLUTION CONSISTED OF:',
     1/,1X,128('*'),/,25X,'ROAD',5X,'ROAD',4X,
     2'LANDING CONST',4X,'LANDING CONST',52X,'TOTAL',/,
     31X,'METHOD',6X,'METHOD',5X,'CONST',4X,'CONST',4X,
     4'AND',4X,'SYSTEM',4X,'AND',4X,'SYSTEM',3X,'SKIDDING',
     54X,'SKIDDING',4X,'TRUCKING',4X,'TRUCKING',4X,'METHOD',
     6/,6X,'#',2X,'PROPORTION',
     15X,'HOURS',4X,'COSTS',12X,'HOURS',12X,'COSTS',
     76X,'HOURS',7X,'COSTS',7X,'HOURS',7X,'COSTS',5X,'COSTS',/)
      DO 1012 I=1,M
      DO 1012 K=1,NMETH
      K2=K+1
      IF(IVAR(I).NE.K2) GO TO 1012
      I1=I1+1
      IARR(I1)=IVAR(I)-1
      TSSUM=TSSUM+P(I)
      ITOT=ITOT+1
      PROP(I1)=P(I)
      I2P=IARR(I1)
      RC(I2P)=LOGMET(2,I2P)*PROP(I1)
      LD(I2P)=LOGMET(3,I2P)*PROP(I1)
      SK(I2P)=LOGMET(4,I2P)*PROP(I1)
      TK(I2P)=LOGMET(5,I2P)*PROP(I1)
      INMIP=INMIP+1
      ROADMC=RC(I2P)*SMDZHC
      LAMOMC=LD(I2P)*(DZRHC(ILOZR)+SYSMHC)
      SKIDMC=SK(I2P)*SMSKHC
      TRUKMC=TK(I2P)*SMTKHC
      SUMRPH=SUMRPH+RC(I2P)
      SUMRPC=SUMRPC+ROADMC
      SUMLPH=SUMLPH+LD(I2P)
      SUMLPC=SUMLPC+LAMOMC
      SUMSPH=SUMSPH+SK(I2P)
      SUMSPC=SUMSPC+SKIDMC
      SUMTPH=SUMTPH+TK(I2P)
      SUMTPC=SUMTPC+TRUKMC
      TOTHRM=ROADMC+LAMOMC+SKIDMC+TRUKMC
      SUMTOT=SUMTOT+TOTHRM
      WRITE(KW,8047)IARR(I1),PROP(I1),RC(I2P),ROADMC,LD(I2P),
     1LAMOMC,SK(I2P),SKIDMC,TK(I2P),TRUKMC,TOTHRM
 8047 FORMAT(3X,I4,6X,F6.2,1X,F9.1,1X,F8.0,8X,F9.1,9X,F8.0,2X,
     1F9.0,4X,F8.0,3X,F9.1,4X,F8.0,1X,F9.0)
 1012 CONTINUE
      WRITE(KW,8048)
 8048 FORMAT(12X,7('-'),1X,9('-'),1X,8('-'),8X,9('-'),9X,
     18('-'),2X,9('-'),4X,8('-'),3X,9('-'),4X,8('-'),1X,9('-'))
      WRITE(KW,8049)TSSUM,SUMRPH,SUMRPC,SUMLPH,SUMLPC,SUMSPH,
     1SUMSPC,SUMTPH,SUMTPC,SUMTOT
 8049 FORMAT(1X,'TOTALS:',5X,F6.2,1X,F9.1,1X,F8.0,8X,F9.1,9X,
     1F8.0,2X,F9.0,4X,F8.0,3X,F9.1,4X,F8.0,1X,F9.0,/,
     21X,128('*'))
      GROSSV=PRODPC*TOTLVL
      GRSMHC=GROSSV-VALUE
      UNITHC=VALUE/TOTLVL
      GMNHUC=PRODPC-UNITHC
      WRITE(KW,8055)GROSSV,PRODPC
 8055 FORMAT(2(/),1X,91('*'),/,1X,'(A) TOTAL DELIVERD PRICE',
     11X,'OF HARVESTED TIMBER:',2X,F13.0,7X,'UNIT PRICE:',3X,F9.2)
      WRITE(KW,8060)GRSMHC,GMNHUC
 8060 FORMAT(1X,'(B) TOTAL HARVESTING COSTS (THOSE CONSIDERED):'
     1,1X,F13.0,7X,'UNIT COSTS:',3X,F9.2,/,54X,7('-'),24X,
     27('-'))
      WRITE(KW,8070)VALUE,UNITHC
 8070 FORMAT(26X,'DIFFERENCE: (A)-(B):',2X,F13.0,21X,F9.2,/,
     191('*'))
      CALL SENS(N,M)
      STOP
      END
      SUBROUTINE SENS(N,M)
C
C*****THIS SUBROUTINE IS THE EXECUTIVE ROUTINE TO INITIALIZE THE
C     SENSITIVITY ANALYSIS.
C
      COMMON C(25),P(25),CMZ(25),A(25,25),ZJ(25),IVAR(25),PCOST(25)
     1,SHADO(25),CL(25),CU(25),CUP(25),CLO(25),BUP(25),BLO(25)
     2,B(25),CC(25),JVAR(25)
     3,IARR(4),PROP(4),RC(4),LD(4),SK(4),TK(4)
C
C*****FIRST, THE LIMITS ON EACH C(J) ARE FOUND.  IF X(L) IS A BASIC
C     VARIABLE, THEN SUBROUTINE CBAS IS CALLED, OTHERWISE SUBROUTINE
C     CNONB IS USED FOR NONBASIC X(L).  IF X(L) IS BASIC, NCUE IS  SET
C     TO 1, OTHERWISE NCUE REMAINS 0.
C
      K=0
      KW=6
    5 NCUE=0
      K=K+1
      L=JVAR(K)
      IF(K.GT.N)GO TO 15
      DO 10 I=1,M
      KV=IVAR(I)
      IF(L-KV)10,20,10
   20 NCUE=1
   10 CONTINUE
      IF(NCUE-1) 25,30,25
   25 CALL CNONB(K,N,M)
      GO TO 5
   30 CALL CBAS(K,N,M)
      GO TO 5
C
C*****NOW,SUBROUTINE BRANG IS CALLED TO DETERMINE THE RANGE [illegible]
C     RIGHT HAND SIDE CONSTANTS B(I).
C
   15 CALL BRANG(N,M)
C
C*****THE FINAL STEP IS TO WRITE THE REPORT.  FIRST, THE SHADOW PRICES
C     AND PENALTY COSTS ARE WRITTEN.  NEXT, THE RANGES ON THE BASIC
C     AND NONBASIC C(J) ARE WRITTEN.  THEN, THE B(I) RANGES ARE
C     DISPLAYED, AND THE SENSITIVITY ANALYSIS IS COMPLETED.  DURING THE
C     WRITE ROUTINES, THE SUBROUTINE CHECK IS CALLED, WHICH DETERMINES
C     IF X(J) IS BASIC OR NONBASIC IN THE OPTIMUM TABLEAU.
C
      WRITE(KW,100)
      WRITE(KW,1000)
      WRITE(KW,101)
      WRITE(KW,102)
      K=0
   11 K=K+1
      IF(K.GT.N) GO TO 31
      CALL CHECK(K,NQUE,N,M)
      IF(NQUE-1) 21,11,21
   21 WRITE(KW,103) JVAR(K),PCOST(K)
CJK
CJK
CJK   WRITES OUT NON-BASIC VARIABLES AND PENALTY COSTS
CJK
CJK
CJK
      GO TO 11
   31 WRITE(KW,149)
CJK
CJK
CJK    WRITES OUT ROW NUMBER AND SHADOW PRICES
CJK
CJK
      DO 22 I=1,M
   22 WRITE(KW,103) I,ZJ(I)
      WRITE(KW,104)
      WRITE(KW,105)
      K=0
   40 K=K+1
      IF(K.GT.N) GO TO 60
      CALL CHECK(K,NQUE,N,M)
      IF(NQUE-1) 50,40,50
   50 WRITE(KW,106) JVAR(K),CL(K)
CJK
CJK
CJK   WRITES OUT RANGES ON NON-BASIC C(J), VARIABLE CODE
CJK   AND ITS LOWER LIMIT
CJK
CJK
      GO TO 40
   60 WRITE(KW,107)
      WRITE(KW,108)
      K=0
   70 K=K+1
      IF(K.GT.N) GO TO 90
      CALL CHECK(K,NQUE,N,M)
      IF(NQUE) 70,70,80
   80 WRITE(KW,109)JVAR(K),CLO(K),CUP(K)
CJK
CJK
CJK  WRITES OUT RANGES ON BASIC C(J), VARIABLE LOWER LIMIT AND
CJK  VARIABLE UPPER LIMIT
CJK
CJK
      GO TO 70
   90 WRITE(KW,110)
      WRITE(KW,111)
      DO 95 I=1,M
      WRITE(KW,112) I,BLO(I),BUP(I)
CJK
CJK
CJK  WRITES OUT VARIABLE CODE AND UPPER AND LOWER LIMIT OF B(I)
CJK
CJK
   95 CONTINUE
  100 FORMAT(1H1,25X,'SENSITIVITY ANALYSIS',2(/),
     110X,'NOTE: VARIABLE CODE NUMBERS USED IN SENSITIVITY',/,
     210X,'ANALYSIS ARE NOT EASY TO CORRELATE WITH OUTPUT',/,
     310X,'COLUMNS AND ROWS FROM LP MATRIX',//,
     410X,'USERS FAMILAR WITH LP SHOULD MAKE CHANGES IN',/,
     510X,'INPUT COSTS (CJ) AND RESOURCE LIMITS (BI) TO',/,
     610X,'BECOME FAMILAR WITH THE SENSITIVITY ANALYSIS AS IT',/,
     710X,'APPLIES TO THE CONVEX-ISOQUANT-METHOD FORMULATION',/,
     810X,'USED IN L-O-S-T',//)
  101 FORMAT(10X,'NON-BASIC',12X,'PENALTY')
  102 FORMAT(10X,'VARIABLES',13X,'COST',/)
  103 FORMAT(13X,I2,13X,F12.3)
  104 FORMAT(4(/),3X,'RANGES ON NON-BASIC C(J)',/)
  105 FORMAT(10X,'VARIABLE',11X,'LOWER LIMIT',/)
  106 FORMAT(13X,I2,14X,F11.3)
  107 FORMAT(4(/),3X,'RANGES ON BASIC C(J)',/)
  108 FORMAT(10X,'VARIABLE',11X,'LOWER LIMIT',11X,'UPPER LIMIT',/)
  109 FORMAT(13X,I2,14X,F11.3,11X,F11.3)
  110 FORMAT(4(/),3X,'RANGES ON B(I)',/)
  111 FORMAT(14X,'I',14X,'LOWER LIMIT',11X,'UPPER LIMIT',/)
  112 FORMAT(13X,I2,14X,F11.3,11X,F11.3)
  149 FORMAT(3(/),13X,'ROW',15X,'SHADOW',/,12X,'NUMBER',13X,
     1'PRICES',/)
 1000 FORMAT(1X,'SHADOW PRICES ARE CHANGE IN OBJECTIVE FUNCTION',
     11X,'VALUE PER UNIT CHANGE',/,6X,'IN RIGHT HAND SIDE',
     21X,'CONSTRAINTS.',2(/),1X,'PENALTY COSTS ARE CHANGE',
     31X,'IN OBJECTIVE FUNCTION VALUE PER UNIT',/,6X,
     4'INCREASE IN NON-BASIC VARIABLES.',2(/),1X,
     5'RANGES ON C(J) REPRESENT LIMITING VALUES OF COST',
     61X,'COEFFICIENTS THAT',/,6X,'WILL NOT CHANGE THE OPTIMUM',
     71X,'SOLUTION',2(//),2X,'RANGES ON B(I) REPRESENT LIMITING',
     81X,'VALUES OF RIGHT HAND SIDE CONSTRAINTS',/,6X,'THAT WILL',
     91X,'NOT CHANGE OPTIMUM BASIC VARIABLES.',2(/))
      RETURN
      END
      SUBROUTINE CHECK(K,NQUE,N,M)
      COMMON C(25),P(25),CMZ(25),A(25,25),ZJ(25),IVAR(25),PCOST(25)
     1,SHADO(25),CL(25),CU(25),CUP(25),CLO(25),BUP(25),BLO(25)
     2,B(25),CC(25),JVAR(25)
     3,IARR(4),PROP(4),RC(4),LD(4),SK(4),TK(4)
C
C*****THIS ROUTINE CHECKS TO SEE IF THE INDEX OF X(L) MATCHES THE
C     INDEX OF ANY OF THE OPTIMUM BASIC VARIABLES.  IF THERE
C     IS A MATCH, NQUE IS SET TO 1, OTHERWISE A VALUE OF ZERO IS
C     RETURNED.
C
      L=JVAR(K)
      NQUE=0
      DO 10 I=1,M
      KV=IVAR(I)
      IF(L-KV) 10,20,10
   20 NQUE=1
   10 CONTINUE
      RETURN
      END
      SUBROUTINE CNONB(K,N,M)
C
C*****THIS ROUTINE DETERMINES THE LOWER LIMIT FOR NONBASIC C(J).
C     THE METHOD USED IS TO FIND THE MINIMUM VALUE OF C(J) SUCH THAT
C     CBAR(J) IN THE OPTIMUM TABLEAU REMAINS NEGATIVE, THUS MAINTAINING
C     OPTIMALITY OF THE CURRENT SOLUTION.
C
      COMMON C(25),P(25),CMZ(25),A(25,25),ZJ(25),IVAR(25),PCOST(25)
     1,SHADO(25),CL(25),CU(25),CUP(25),CLO(25),BUP(25),BLO(25)
     2,B(25),CC(25),JVAR(25)
     3,IARR(4),PROP(4),RC(4),LD(4),SK(4),TK(4)
      J=1
      ZZ=0.
   10 KV=IVAR(J)
      ZZ=ZZ+CC(KV)*A(J,K)
      J=J+1
      IF(J.GT.M) GO TO 20
      GO TO 10
   20 CL(K)=ZZ
      CU(K)=999999.
C
C*****INCLUDED IN THIS ROUTINE IS THE IDENTIFYING OF THE PENALTY
C     COST OF THE NONBASIC VARIABLES.  IT SHOULD BE
C     NOTED THAT IF THE PENALTY COST OF ANY NONBASIC X(J) IS ZERO,
C     THE PROBLEM HAS AN ALTERNATIVE OPTIMUM SOLUTION USING X(J).
C
      PCOST(K)=CMZ(K)
      RETURN
      END
      SUBROUTINE CBAS(K,N,M)
C
C     THIS SUBROUTINE DETERMINES THE RANGE ON OPTIMAL BASIC C(J)
C
      DIMENSION ZS(60)
      COMMON C(25),P(25),CMZ(25),A(25,25),ZJ(25),IVAR(25),PCOST(25)
     1,SHADO(25),CL(25),CU(25),CUP(25),CLO(25),BUP(25),BLO(25)
     2,B(25),CC(25),JVAR(25)
     3,IARR(4),PROP(4),RC(4),LD(4),SK(4),TK(4)
C
C*****FIRST, A MAXIMUM LIMIT IS SET ON THE UPPER AND LOWER BOUND
C     FOR C(J).  IF THE FINAL RESULT IN THE OUTPUT IS THIS
C     MAXIMUM VALUE IT CAN BE ASSUMED THAT THE LIMIT DOES NOT EXIst.
C
      CUP(K)=999999.
      CLO(K)=-999999.
C
C*****THE LIMITS ON BASIC C(J) ARE DETERMINED BY THE VALUES OF THE
C     NONBASIC C(J)'S.  EACH NONBASIC C(J) IS TREATED SEPARATELY, AND
C     A LIMIT ON C(J) IS DETERMINED BY FINDING THE MAX OR MIN VALUE
C     C(J) MAY HAVE IN ORDER TO MAINTAIN THAT CBAR(J) NEGATIVE.
C
      J=0
   10 J=J+1
      IF(J.GT.N) GO TO 75
C
C*****ZS(J) IS THE VALUE OF THE SUM OF THE INNER PRODUCTS OF CB AND
C     ABAR, EXCLUDING THE TERM INVOLVING THE BASIC C(J).
C
      ZS(J)=0.
      I=0
   15 I=I+1
      IF(I.GT.M) GO TO 20
      IF(JVAR(J).EQ.IVAR(I)) GO TO 10
      GO TO 15
   20 L=0
   22 L=L+1
   25 IF(L.GT.M) GO TO 30
      LV=IVAR(L)
      IF(LV.EQ.JVAR(K)) GO TO 35
      ZS(J)=ZS(J)+CC(LV)*A(L,J)
      GO TO 22
   35 NI=L
      GO TO 22
C
C*****IF A(NI,J) IS SMALL, IT IS IGNORED BECAUSE IT APPEARS IN THE
C     DENOMINATOR.  OTHERWISE, IF IT IS POSITIVE, A LOWER LIMIT IS
C     FOUND, AND IF IT IS NEGATIVE, AN UPPER LIMIT IS FOUND.  THESE
C     VALUES ARE THEN COMPARED TO THE PRESENT LIMITS.  IF THEY ARE MORE
C     RESTRICTIVE THAN THE PRESENT LIMITS, THE PRESENT LIMITS ARE
C     REVISED.
C
   30 IF(ABS(A(NI,J)).LT.1.E-08) GO TO 10
      IF(A(NI,J)) 40,10,50
   40 TCU= (C(J)-ZS(J))/A(NI,J)
      IF(TCU.LT.CUP(K)) CUP(K)=TCU
      GO TO 10
   50 TCL= (C(J)-ZS(J))/A(NI,J)
      IF(TCL.GT.CLO(K)) CLO(K)=TCL
      GO TO 10
   75 CONTINUE
      RETURN
      END
      SUBROUTINE BRANG(N,M)
C
C*****THIS ROUTINE DETERMINES THE RANGES ON ALL B(I).
C
      DIMENSION PPRIME(40)
      COMMON C(25),P(25),CMZ(25),A(25,25),ZJ(25),IVAR(25),PCOST(25)
     1,SHADO(25),CL(25),CU(25),CUP(25),CLO(25),BUP(25),BLO(25)
     2,B(25),CC(25),JVAR(25)
     3,IARR(4),PROP(4),RC(4),LD(4),SK(4),TK(4)
      K=0
   30 K=K+1
      IF(K.GT.M)GO TO 35
C
C*****INITIAL UPPER AND LOWER BOUNDS ON B(K) ARE SET.
C
      BUP(K)=999999.
      BLO(K)=-999999.
      I=0
   20 I=I+1
      IF(I.GT.M) GO TO 30
C
C*****PPRIME IS THE VALUE OF THE SUM OF THE INNER PRODUCT B-INVERSE
C     TIMES B(I), EXCLUDING THE TERM INVOLVING THE B(K) WE ARE FINDING
C     LIMITS FOR.
C
      PPRIME(I)=0.
      J=0
   10 J=J+1
      IF(J.GT.M) GO TO 25
      IF(J.EQ.K)GO TO 15
      PPRIME(I)=PPRIME(I)+A(I,J)*B(J)
      GO TO 10
   15 NI=J
      GO TO 10
C
C*****IF A(I,NI) IS SMALL, IT IS IGNORED.  PRESENT LIMITS ARE THEN
C     REVISED IF IMPROVEMENTS ARE POSSIBLR.
C
   25 IF(ABS(A(I,NI)).LT.1.E-8) GO TO 20
      IF(A(I,NI)) 26,20,27
   26 TBU=-PPRIME(I)/A(I,NI)
      IF(TBU.LT.BUP(K)) BUP(K)=TBU
      GO TO 20
   27 TBL=-PPRIME(I)/A(I,NI)
      IF(TBL.GT.BLO(K)) BLO(K)=TBL
      GO TO 20
   35 RETURN
      END
/GO

                    data cards go here

//
```

Koger, Jerry L. and Webster, Dennis B. 1984. L-O-S-T: *L*ogging *O*ptimization *S*election *T*echnique. U. S. Dept. of Agric. For. Serv. Res. Pap. SO-203, 66 p. South. For. Exp. Stn. New Orleans, La.

L-O-S-T is a FORTRAN computer program developed to systematically quantify, analyze, and improve user selected harvesting methods. Harvesting times and costs are computed for road construction, landing construction, system move between landings, skidding, and trucking. A linear programming formulation utilizing the relationships among marginal analysis, isoquants, and the harvesting methods is used to estimate and select the harvesting procedure having maximum profits.

Additional keywords: optimization, harvesting, computer program, roadbuilding, skidders, hauling.

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Sweetgum Volume and Weight Tables

Bryce E. Schlaegel

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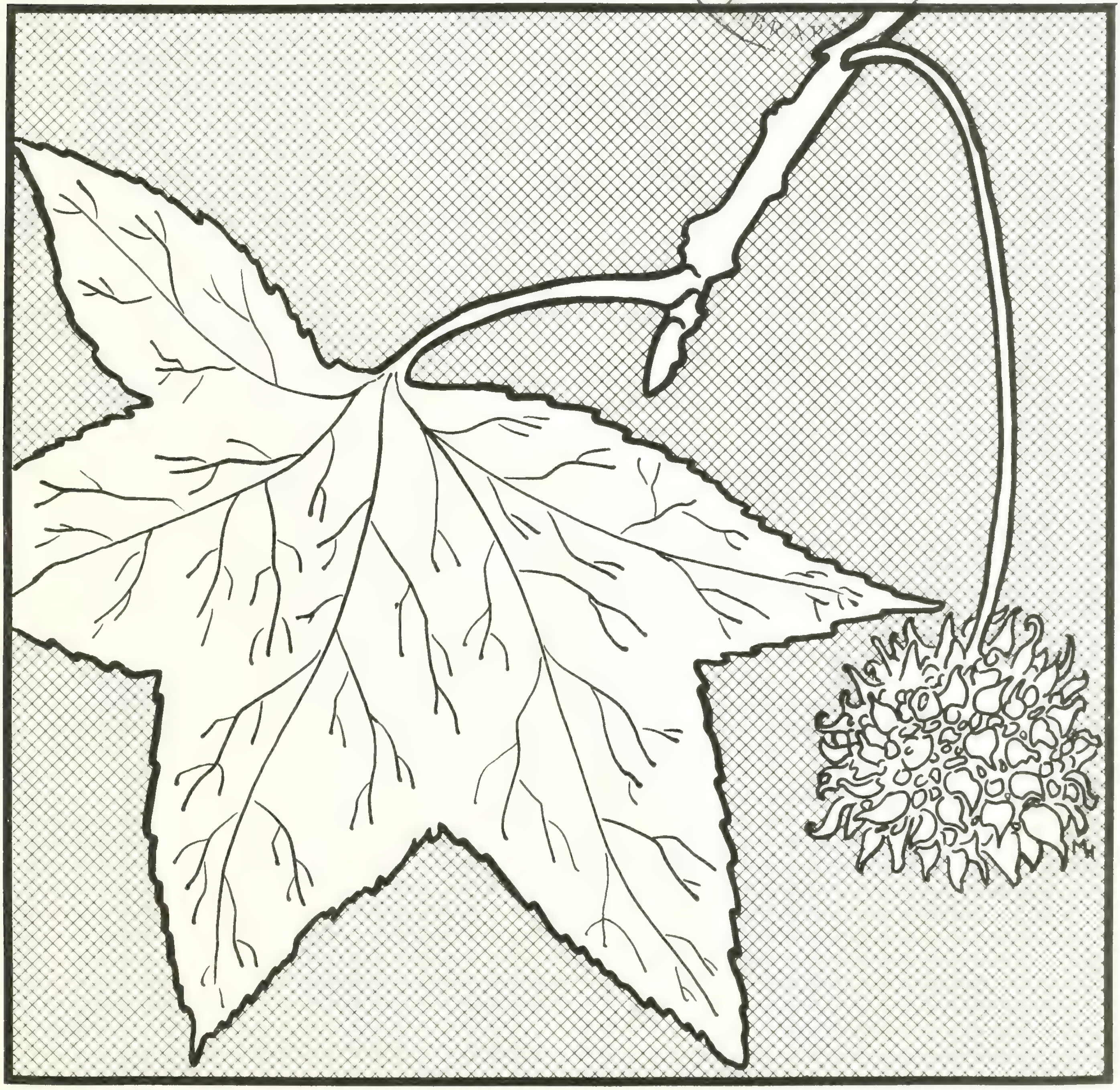

SUMMARY

Volume and weight tables were constructed from a 54-tree sample of sweetgum *(Liquidambar styraciflua* L.) taken in the Mississippi Delta. The tables present cubic-foot volume, green weight, and dry weight of bole wood, bole wood plus bark, and total tree excluding leaves above a 1-foot stump as predicted from the allometric model $\mathrm{Ln}\ Y = b_0 + b_1 \mathrm{Ln}(D^2H)$. Merchantable bole volume and weight estimates can be made to any outside bark diameter limit. More precise bole estimates can be obtained from equations using upper bole diameters taken at relative heights of 25, 33, and 50 percent of total tree height.

Sweetgum Volume and Weight Tables

Bryce E. Schlaegel

INTRODUCTION

Sweetgum *(Liquidambar styraciflua* L.) grows in the United States from Connecticut southward throughout the East to central Florida (except for the high mountains), east to Texas, north through Arkansas and southeastern Missouri to southern Illinois, Indiana, Ohio, and West Virginia (Little 1979) (fig. 1). It is very tolerant of different soils but grows best on the rich, moist clay and loam soils of river bottoms. On good sites it can develop a large, clear bole, reach a height of 140 feet, and have a dbh in excess of 36 inches. Commonly the trees reach heights of 100 to 120 feet with dbh ranging from 24 to 28 inches.

In recent years there has been considerable demand for volume and weight tables for bottomland hardwood species. This paper is the fifth in a series of six giving both volume and weight tables for some of the major bottomland hardwood species. The other five species in the series are willow oak *(Quercus phellos* L.) (Schlaegel 1981), Nuttall oak *(Q. nuttallii* Palmer) (Schlaegel and Willson 1983), sugarberry *(Celtis laevigata* Willd.) (Schlaegel 1984a), overcup oak *(Q. lyrata* Walt.) (Schlaegel 1984b), and green ash *(Fraxinus pennsylvanica* Marsh.) (Schlaegel 1984c).

METHODS

The data were collected from 10 natural bottomland hardwood stands in west-central Mississippi. Stands were either even- or uneven-aged with a mixed species composition. Each stand was measured for species composition and diameter distribution; 54 trees, ranging in dbh from 1 through 33 inches, were chosen for destructive sampling. The sample consisted of growing stock trees from both the overstory and understory with healthy crowns and no visible signs of disease or decay. When available, three trees were selected from each 1-inch diameter class. Cutting was done throughout the year.

Stump height and total height were measured on each felled sample tree. Disks about 1-inch thick were cut from the bole at regular intervals from the stump to the top of the tree. These were then sealed in separate polyethylene bags for laboratory determination of moisture content and specific gravity. The first disk was at stump height and the remainder at 5-foot intervals measured from ground level for trees 5 inches dbh and larger and at 3-foot intervals for trees smaller than 5 inches dbh. All limbs, including leaves, were weighed on 49 of the trees.

In the laboratory, both wood and bark moisture content and specific gravity were determined as follows:

1. Wood and bark were separated with a hammer and chisel.
2. Each component was weighed green.
3. Both wood and bark were soaked in water for at least an hour to ensure complete swelling.
4. Volumes were obtained by immersion (Heinrichs and Lassen 1970).
5. Wood and bark were dried in a forced-air oven at 105°C for at least 48 hours.
6. Wood or bark moisture content = $$\frac{\text{green weight} - \text{ovendry weight}}{\text{ovendry weight}}$$
7. Specific gravity = $$\frac{\text{ovendry wood or bark weight (g)}}{\text{green wood or bark volume (cm}^3\text{)}}$$

Average tree moisture content and specific gravity were calculated from weighted averages of the disk moisture content and specific gravities; each disk specific gravity or moisture content was weighted by its squared average diameter.

Taper functions (Schlaegel 1981, Schlaegel and Willson 1983) of the form

$$Y = b_1(X^1 - 1) + b_2(X^2 - 1) + \ldots + b_p(X^p - 1)$$

where

Y = d/D,
d = diameter at height h on the bole,
D = dbh,
X = h/H,
h = height from ground to a specific measurement point,

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H = total height,

b_i = coefficients estimated for each tree by linear regression; $i = 1, 2, \ldots p$; $4 \leq p \leq 7$,

were calculated for each tree, both inside and outside bark. Cubic-foot volumes were obtained for each tree by integrating the taper function to heights of specific top diameters to obtain both total and merchantable bole volumes. Bole green and dry weights were calculated from estimated tree volume and weighted average tree density and moisture content.

Allometric regression equations were used to estimate volume, green weight, and dry weight of bole wood, bole wood plus bark, and bole wood plus bark plus limbs.

RESULTS

Characteristics of the trees used in this study are:

	Average	Range
Dbh *(in)*	14.0	0.9 – 32.5
Total height *(ft)*	80	13 – 128
Wood moisture content *(percent)*	119	97 – 150
Bark moisture content *(percent)*	100	62 – 216
Wood specific gravity	0.469	0.256 – 0.523
Bark specific gravity	0.418	0.270 – 0.569
Wood + bark green density *(lb/ft³)*	62.46	43.46 – 66.41
Wood + bark dry density *(lb/ft³)*	28.85	17.76 – 32.15
Wood + bark moisture content *(percent)*	117	102 – 154
Wood + bark specific gravity	0.462	0.284 – 0.515

Individual tree volumes and weights were fitted to the allometric model:

$$\mathrm{Ln}(Y) = b_0 + b_1 \,\mathrm{Ln}(D^2H) \qquad (1)$$

where

Y = the volume or weight variable of interest,

Ln is a natural logarithm;

b_0 and b_1 are coefficients estimated from the data.

Estimates of the coefficients b_0 and b_1 are presented in table 1 for predicting cubic foot volume and green and dry weight of bole wood, bole bark, total

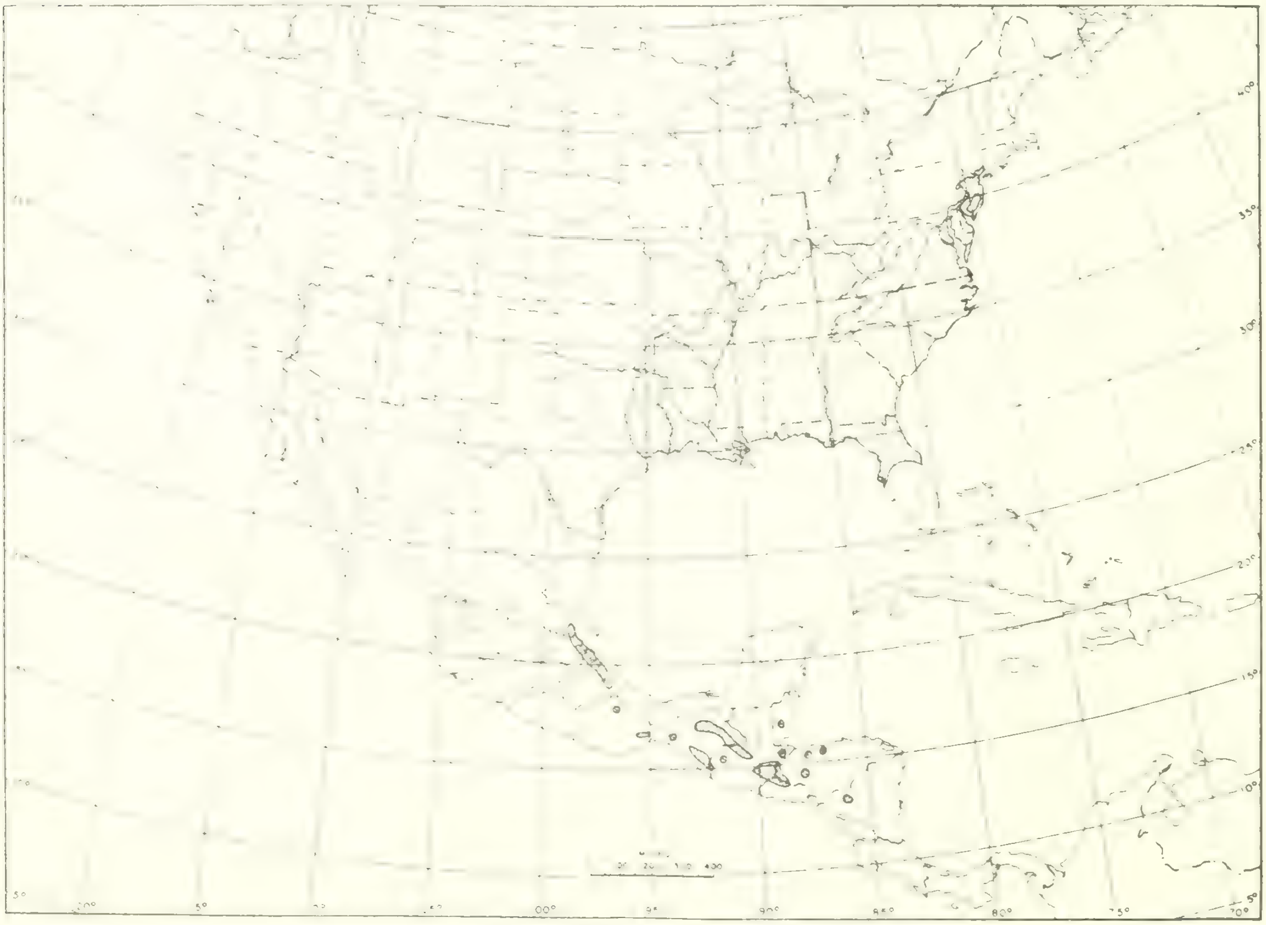

Figure 1.—*The range of sweetgum (Fowells 1965). (F-506604)*

bole, and total tree excluding leaves. Additional statistics presented are the component average, fit index, regression standard error of estimate ($\hat{S}_e$) based on residuals after converting to actual units, and coefficient of variation (C.V.) of predictions in arithmetic units. Fit index, which is similar to R^2, is used to judge equation efficiency when the dependent variable has been transformed (Farrar 1978) and is calculated in untransformed units from the total and residual sums of squares.[1] The fit index and R^2 are equal when a simple linear regression analysis is performed on an untransformed dependent variable.

Fit indices range from 0.933 for dry bole bark weight to 0.982 for dry total bole weight. A fit index of 1.0 indicates that predictions can be made without error with the data used to fit the model; a value close to 1 is desirable. Coefficients of variation, which are indices of relative precision of prediction, range from 25.1 percent for dry bole bark weight to 14.5 percent for total bole volume.

Using measures of individual tree dbh and total height, estimates can be made using table 1 for tree volume (given in table 2), green weight (given in table 3), and dry weight (given in table 4) for bole wood, bole wood plus bark, and for bole wood plus bark plus limbs excluding leaves.

The equations were developed using trees from a limited geographic range compared to the total range. Therefore, predictions may be less precise when the equations are applied in other parts of the range. Using an upper bole diameter measurement in addition to dbh as described later should alleviate this problem.

MERCHANTABLE BOLE ESTIMATES

The merchantable bole is defined as the tree bole from a 1-foot stump to a specified top diameter, ignoring limbs. Merchantable bole volume or weight can be expressed as a proportion of the total bole by a generalized form of the logistic model

$$R_I = (1.0 + e^{f(X)})^{-1} \tag{2}$$

where

R_I = ratio of merchantable bole volume or weight to total bole volume or weight, where I = top outside bark diameter of merchantable bole,

$X = (D - d_I)/D$,

D = tree dbh outside bark, and

d_I = outside bark top diameter.

For a specific top diameter, the ratio of merchantable bole to total bole is the same for volume, green weight, dry weight, and inside and outside bark (Schlaegel and Willson 1983).

Model 2 was fitted to the overcup oak data for trees ≥ 4.6 inches dbh, with $f(X) = b_0 + b_1X + b_2X^2 + b_3X^3 + b_4X^4$. Inverting (2) and taking the natural logarithm results in

$$\mathrm{Ln}\left(\frac{1 - R_I}{R_I}\right) = b_0 + b_1X + b_2X^2 + b_3X^3 + b_4X^4;$$

this was solved using multiple linear regression techniques giving:

$$\begin{aligned} R_I = [1.0 + \mathrm{EXP}\,(0.78495 + 10.76197\,X \\ - 77.22807\,X^2 + 121.11402\,X^3 \\ - 65.62841\,X^4)]^{-1} \end{aligned} \tag{3}$$

with fit index = 0.935 and $\hat{S}_e = 0.047$; EXP is the base of the natural logarithm and equals 2.71828.

Volume or weight to any top diameter (V_I) is found by multiplying the ratio estimate obtained from (3) by a total bole volume or weight estimate from either table 2, 3, or 4:

$$V_I = R_I \cdot V_T,$$

where V_T is the total bole volume or weight of interest.

IMPROVED TOTAL BOLE ESTIMATES

The precision of the merchantable bole estimate depends upon accuracy in measuring total bole. Total bole estimates can be significantly improved by measuring one or two additional diameters. Tables 5 and 6 give regression statistics for total bole volume and weight under two different model forms:

$$\mathrm{Ln}(Y) = b_0 + b_1\,\mathrm{Ln}(D \cdot D_{1/3} \cdot H) \tag{4}$$

and

$$\mathrm{Ln}(Y) = b_0 + b_1\,\mathrm{Ln}[(D \cdot D_{1/2} + D^2_{1/4}) \cdot H] \tag{5}$$

where D, H, and Y are as defined previously, and $D_{1/3}$, $D_{1/2}$, and $D_{1/4}$ are diameters measured outside the bark at one-third, one-half, and one-fourth the total height.

Statistics from tables 5 and 6 show the significant ($\propto = 0.05$) improvement over the previous D^2H equations of table 1. Measuring one additional diameter at one-third the tree height reduces $\hat{S}_e$ for bole wood volume, total bole volume, green bole wood weight, total green bole weight, dry bole wood weight, and total dry bole weight by 42, 43, 36, 39, 38, and 40 percent, respectively. Other standard errors are reduced but not significantly.

Measuring two upper bole diameters at one-fourth and one-half total height will result in further significant increases in precision. Improvements over the D^2H model range from 53 to 70 percent for bole wood and total bole volume and weight.

Taking additional bole measures means a higher inventory cost, since more time will be spent at each tree, but most of the inventory cost is in traveling to the candidate tree. Data presented in this paper allow total and merchantable bole estimates to be made with high reliability. Each user has to decide when increased precision is needed and whether the need offsets the higher cost.

---

[1] $FI = \{1 - [\Sigma(Y_i - \hat{Y}_i)^2] / [\Sigma(Y_i - \bar{Y})^2]\}$

LOCAL VOLUME TABLES

There are many occasions when the only tree variable available is dbh, or perhaps only a rough estimate of tree volume or weight is needed. In these cases a local volume table will suffice. Table 7 gives the statistics needed for estimating by the local volume table technique. However, it must be realized that estimation precision may be considerably lessened. The local volume or weight model is

$$\mathrm{Ln}(Y) = b_0 + b_1\,\mathrm{Ln}(D^2). \tag{6}$$

Precision is significantly ($\alpha = 0.05$) reduced when only dbh is used to predict all measured portions of the tree except bark.

CALCULATING CONFIDENCE LIMITS

Confidence limits ($(1-\alpha)$ percent confidence limits) of individual predictions can be calculated using the statistics presented in table 8. Clark et al. (1980) used the technique of Land (1972) to estimate approximate confidence limits for lognormal means of scarlet oak:

$$Y_{U.L.} = \mathrm{EXP}\left\{ \mathrm{Ln}(Y) \pm Z_{\alpha/2}\left[S^2_{y\cdot x}\left[\frac{1}{n} + \frac{(X-\overline{X})^2}{\Sigma(X-\overline{X})^2}\right] + \frac{S^4_{y\cdot x}}{2(n+1)}\right]^{1/2} \right\}$$

where:

$Y_{U.L.}$ = upper and lower limits for Y,
EXP = base of natural logarithm; EXP = e = 2.71828,
Y = predicted volume or weight of component,
$Z_{\alpha/2}$ = value for the upper $\alpha/2$ percentage point from the standard normal table,
$S_{y\cdot x}$ = standard error of estimate for prediction equation,
n = number of observations used to develop the equation,
$\overline{X}$ = sample mean of Ln(X),
$\Sigma(X-\overline{X})^2$ = corrected sum of squares for Ln(X),
X = $\mathrm{Ln}(D^2H)$; D = dbh and H = total height of tree for which Y is predicted.

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Table 1.—*Regression statistics for predicting sweetgum tree volumes and weights using dbh and total height*[1]

Component	Average Y	b_0	b_1	Fit index[2]	$\hat{S}_e$[3]	C.V. percent[4]
			Volume *(cubic feet)*			
Bole wood	48.5	−6.048	0.97280	0.981	7.30	15.1
Bole bark	5.8	−7.123	0.87919	0.935	1.41	24.2
Total bole	54.3	−5.778	0.95842	0.982	7.89	14.5
Total tree, excluding leaves	74.0	−5.658	0.96634	0.972	12.55	17.0
			Green weight *(pounds)*			
Bole wood	3173	−2.062	0.99191	0.979	512	16.1
Bole bark	293	−3.138	0.87359	0.940	68	23.1
Total bole	3466	−1.797	0.97525	0.980	535	15.4
Total tree, excluding leaves	4719	−1.682	0.98331	0.971	823	17.4
			Dry weight *(pounds)*			
Bole wood	1460	−2.926	1.00069	0.981	222	15.2
Bole bark	163	−4.317	0.93023	0.933	41	25.1
Total bole	1623	−2.693	0.98877	0.982	238	14.6
Total tree, excluding leaves	2212	−2.579	0.99672	0.975	362	16.4

[1] Volumes and weights of trees from a 1-foot stump to the tree tip, using $\mathrm{Ln}(Y) = b_0 + b_1 \mathrm{Ln}(D^2H)$; D = dbh, H = total tree height.

[2] Fit index = $1.0 - [\Sigma(Y - \hat{Y})^2 / \Sigma(Y - \bar{Y})^2]$, using untransformed values.

[3] $\hat{S}_e = [\Sigma(Y - \hat{Y})^2 / (n - 2)]^{1/2}$, using untransformed values.

[4] Coefficient of variation = $100\, \hat{S}_e / \bar{Y}$.

Table 2.—*Cubic-foot volume for sweetgum bole wood, bole wood plus bark, and total tree*[1]

Dbh	Total height in feet													
	10	20	30	40	50	60	70	80	90	100	110	120	130	140
inches	*cubic feet*													
1	0.02[2]	0.04	0.06											
	0.03[3]	0.05	0.08											
	0.03	0.06	0.09											
2	0.09	0.17	0.25	0.33										
	0.11	0.21	0.30	0.40										
	0.12	0.24	0.36	0.47										
3		0.37	0.55	0.72	0.90									
		0.45	0.66	0.87	1.08									
		0.53	0.78	1.03	1.28									
4			0.96	1.27	1.58	1.88								
			1.15	1.51	1.88	2.23								
			1.36	1.80	2.23	2.66								
5			1.48	1.96	2.43	2.90	3.37							
			1.76	2.32	2.88	3.43	3.97							
			2.09	2.77	3.43	4.09	4.75							
6				2.79	3.47	4.14	4.81	5.48						
				3.29	4.08	4.86	5.63	6.40						
				3.93	4.88	5.82	6.76	7.69						
7				3.77	4.68	5.59	6.49	7.39	8.29					
				4.43	5.48	6.53	7.57	8.60	9.63					
				5.30	6.57	7.84	9.10	10.30	11.60					
8				4.89	6.07	7.25	8.42	9.59	10.7					
				5.72	7.08	8.43	9.77	11.10	12.4					
				6.86	8.51	10.10	11.80	13.40	15.0					

Table 2.—*Cubic-foot volume for sweetgum bole wood, bole wood plus bark, and total tree—(Continued)*

Dbh	Total height in feet													
	10	20	30	40	50	60	70	80	90	100	110	120	130	140
inches	*cubic feet*													
9				6.14 7.17 8.61	7.63 8.87 10.70	9.11 10.60 12.70	10.6 12.2 14.8	12.1 13.9 16.8	13.5 15.6 18.9					
10					9.37 10.90 13.10	11.2 12.9 15.6	13.0 15.0 18.1	14.8 17.0 20.6	16.6 19.1 23.1	18.4 21.1 25.6				
11					11.3 13.0 15.7	13.5 15.5 18.8	15.6 18.0 21.8	17.8 20.4 24.8	20.0 22.9 27.8	22.1 25.3 30.8				
12					13.4 15.4 18.6	15.9 18.3 22.2	18.5 21.3 25.8	21.1 24.2 29.3	23.7 27.1 32.9	26.2 29.9 36.4	28.8 32.8 39.9			
13						18.6 21.4 25.9	21.7 24.8 30.1	24.7 28.2 34.2	27.6 31.5 38.4	30.6 34.9 42.5	33.6 38.2 46.6			
14						21.5 24.6 29.9	25.0 28.6 34.7	28.5 32.5 39.5	31.9 36.4 44.3	35.4 40.2 49.0	38.8 44.1 53.8			
15						24.6 28.1 34.2	28.6 32.6 39.7	32.6 37.1 45.2	36.5 41.5 50.6	40.5 45.9 56.0	44.4 50.3 61.4			
16						27.9 31.8 38.7	32.4 36.9 45.0	36.9 41.9 51.2	41.4 47.0 57.3	45.9 51.9 63.5	50.3 56.9 69.6			
17						31.4 35.8 43.6	36.5 41.5 50.6	41.6 47.1 57.5	46.6 52.7 64.5	51.6 58.3 71.4	56.6 63.9 78.2	61.7 69.5 85.1		
18						35.1 39.9 48.6	40.8 46.3 56.5	46.4 52.6 64.2	52.1 58.9 72.0	57.7 65.1 79.7	63.3 71.3 87.4	68.9 77.5 95.1		
19						39.0 44.3 54.0	45.3 51.3 62.7	51.6 58.3 71.3	57.9 65.3 79.9	64.1 72.2 88.5	70.3 79.1 97.0	76.5 86.0 106.0	82.7 92.9 114.0	
20							50.1 56.6 69.2	57.0 64.3 78.7	63.9 72.0 88.2	70.8 79.7 97.7	77.7 87.3 107.0	84.6 94.9 117.0	91.4 102.0 126.0	98.3 110.0 135.0
21							55.1 62.2 76.1	62.7 70.6 86.5	70.3 79.1 97.0	77.9 87.5 107.0	85.5 95.9 118.0	93.0 104.0 128.0	101 113 138	108 121 149
22							60.3 68.0 83.2	68.6 77.2 94.7	77.0 86.5 106.0	85.3 95.6 117.0	93.6 105.0 129.0	102 114 140	110 123 151	118 132 163
23							65.7 74.0 90.7	74.8 84.1 103.0	83.9 94.2 116.0	93.0 104.0 128.0	102 114 140	111 124 153	120 134 165	129 144 177
24								81.3 91.2 112.0	91.2 102.0 126.0	101 113 139	111 124 152	121 135 166	130 145 179	140 156 192
25								88.0 98.7 121.0	98.7 110.0 136.0	109 122 150	120 134 165	131 146 179	141 157 194	152 169 208
26								95.0 106.0 131.0	107 119 147	118 132 162	129 144 178	141 157 193	152 169 209	164 182 225

Table 2.—*Cubic-foot volume for sweetgum bole wood, bole wood plus bark, and total tree—(Continued)*

	Total height in feet													
Dbh	10	20	30	40	50	60	70	80	90	100	110	120	130	140
inches	*cubic feet*													
27								102	115	127	**139**	152	164	176
								114	128	142	**155**	169	182	196
								141	158	175	**191**	208	225	242
28								110	123	136	150	163	176	189
								123	137	152	166	181	195	210
								151	169	187	205	223	241	259
29								117	132	146	160	175	188	202
								131	147	162	178	193	209	224
								161	181	200	220	239	258	277
30									141	156	171	186	201	216
									157	173	190	206	223	239
									193	214	235	255	276	296
31									150	166	182	198	214	231
									167	185	202	220	237	255
									206	228	250	272	294	315
32									160	177	194	211	228	245
									177	196	215	234	252	271
									219	242	266	289	312	335
33									169	188	206	**224**	242	260
									188	208	228	**248**	268	287
									232	257	282	**307**	331	356
34									180	199	218	237	257	276
									199	220	241	262	283	304
									246	272	299	325	351	377
35									190	210	231	251	272	292
									211	233	255	277	300	322
									260	288	316	344	371	399
36									201	222	244	265	287	308
									222	246	269	293	316	339
									275	304	334	363	392	421

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[1] Tree volume from a 1-foot stump to the tree tip.

[2] The three vertical figures for each dbh give volumes of bole wood first, bole wood plus bark second, and total tree (bole wood plus bark plus limbs excluding leaves) last.

[3] Boldface numbers span the range of the data.

Table 3.—*Green weight in pounds for sweetgum bole wood, bole wood plus bark, and total tree*[1]

	Total height in feet													
Dbh	10	20	30	40	50	60	70	80	90	100	110	120	130	140
inches	*pounds*													
1	1.2[2]	2.5	3.7											
	1.6[3]	3.1	4.6											
	1.8	3.5	5.3											
2	4.9	9.8	14.7	20										
	6.0	11.9	18.0	23										
	7.0	13.8	21.0	27										
3		22	33	44	54									
		26	39	52	64									
		31	46	61	76									
4			58	77	96	116								
			68	90	112	134								
			81	107	133	159								
5			90	120	150	180	210							
			106	140	174	208	241							
			125	166	206	247	287							
6				173	215	258	301	343						
				199	248	296	344	392						
				237	295	353	411	469						
7				234	293	351	408	466	524					
				269	335	400	465	530	594					
				321	400	479	557	635	713					
8				306	381	457	532	608	683					
				350	434	519	603	687	771					
				418	520	622	724	826	927					
9				386	482	577	673	768	863					
				440	547	653	759	865	970					
				527	656	785	913	1041	1169					
10					594	711	829	946	1063	1181				
					671	802	932	1062	1191	1320				
					807	965	1123	1281	1438	1595				
11					717	859	1001	1143	1285	1426				
					809	966	1123	1279	1434	1590				
					973	1164	1355	1545	1734	1924				
12					852	1021	1190	1359	1527	1695	1863			
					958	1145	1330	1515	1700	1884	2067			
					1155	1381	1608	1833	2058	2283	2507			
13						1197	1395	1592	1790	1987	2184			
						1338	1555	1771	1987	2202	2417			
						1617	1882	2146	2409	2672	2935			
14						1387	1616	1845	2073	2302	2530			
						1546	1797	2047	2296	2544	2792			
						1871	2177	2482	2787	3091	3395			
15						1590	1853	2115	2377	2639	2901			
						1769	2056	2342	2627	2911	3195			
						2142	2493	2843	3192	3540	3888			
16						1807	2106	2404	2702	3000	3297			
						2006	2332	2656	2979	3301	3623			
						2432	2831	3228	3624	4020	4415			
17						2038	2375	2711	3047	3383	3718	4054		
						2258	2624	2989	3353	3716	4078	4439		
						2740	3189	3636	4083	4529	4974	5418		
18						2283	2660	3037	3413	3789	4165	4540		
						2524	2934	3342	3748	4154	4559	4963		
						3066	3568	4069	4569	5067	5565	6062		
19						2541	2961	3381	3800	4218	4636	5054	5472	
						2805	3260	3713	4165	4616	5066	5514	5962	
						3410	3969	4525	5081	5636	6190	6742	7295	

Table 3.—*Green weight in pounds for sweetgum bole wood, bole wood plus bark, and total tree—(Continued)*

	Total height in feet													
Dbh	10	20	30	40	50	60	70	80	90	100	110	120	130	140
inches	*pounds*													
20							3278	3743	4207	4670	**5133**	5596	**6058**	6520
							3603	4104	4604	5102	**5599**	6095	**6590**	7083
							4390	5006	5620	6234	**6847**	7458	**8069**	8679
21							3612	4123	**4634**	5145	5655	6164	6674	7183
							3963	4514	**5063**	5611	6158	6703	7247	7791
							4823	5510	**6187**	6862	7536	8209	8881	9553
22							3961	4522	5082	**5642**	6201	**6760**	7319	7877
							4339	4943	5544	**6144**	6743	**7340**	7936	8531
							5295	6038	6779	**7519**	8258	**8996**	9732	10468
23							4326	4939	**5551**	**6162**	**6773**	7384	7994	8603
							4732	5390	**6046**	**6701**	**7353**	8005	8655	9303
							5779	6589	**7399**	**8206**	**9012**	9817	10621	11424
24								5374	6040	6705	7370	**8034**	8698	9361
								5857	6570	7281	7990	**8698**	9409	10108
								7165	8044	8923	9799	**10674**	11549	12422
25								5827	6549	7271	7991	**8712**	**9432**	10151
								6342	7114	7884	8652	**9418**	**10183**	10946
								7764	8717	9668	10618	**11567**	**12514**	13460
26								6298	7079	7859	8638	9417	10195	10972
								6846	7680	8511	9340	10167	10993	11817
								8386	9416	10444	11470	12494	13517	14539
27								6788	7629	8470	**9310**	10149	10987	11825
								7369	8267	9161	**10053**	10944	11832	12719
								9032	10141	11248	**12353**	13457	14559	15659
28								7296	8200	9103	10006	10908	11809	12710
								7911	8874	9835	10793	11748	12702	13654
								9702	10893	12082	13269	14455	15638	16820
29								7822	8791	9760	10727	11694	12661	13627
								8472	9503	10531	11557	12581	13602	14621
								10395	11671	12945	14217	15487	16756	18022
30									9403	10439	11474	12508	13542	14574
									10152	11251	12347	13441	14532	15621
									12476	13838	15198	16555	17911	19265
31									10035	11140	12245	13349	14452	15554
									10823	11994	13163	14328	15492	16653
									13307	14760	16210	17658	19104	20548
32									10687	11865	13041	14216	15391	16565
									11514	12761	14003	15244	16481	17717
									14164	15711	17254	18796	20335	21872
33									11360	12611	13862	**15111**	16360	17608
									12227	13550	14870	**16187**	17501	18812
									15048	16691	18331	**19968**	21603	23236
34									12053	13381	14708	16033	17358	18682
									12960	14362	15761	17157	18550	19940
									15958	17700	19439	21175	22909	24641
35									12766.	14173	15578	16982	18386	19788
									13714	15198	16678	18155	19629	21100
									16894	18738	20579	22418	24253	26087
36									13500	14987	16474	17958	19442	20925
									14488	16056	17620	19181	20738	22292
									17857	19806	21752	23695	25635	27573

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[1] Tree weight from a 1-foot stump to the tree tip.

[2] The three vertical figures for each dbh give weights of bole wood first, bole wood plus bark second, and total tree (bole wood plus bark plus limbs excluding leaves) last.

[3] Boldface numbers span the range of the data.

Table 4.—*Dry weight in pounds for sweetgum bole wood, bole wood plus bark, and total tree*[1]

	Total height in feet													
Dbh	10	20	30	40	50	60	70	80	90	100	110	120	130	140
inches	*pounds*													
1	0.5[2]	1.1	1.6											
	0.7[3]	1.3	1.9											
	0.7	1.5	2.2											
2	2.1	4.3	6.4	8.6										
	2.6	5.1	7.7	10.2										
	3.0	6.0	9.0	11.9										
3		9.7	14.5	19	24									
		11.5	17.0	23	28									
		13.4	20.0	27	33									
4			26	34	43	52								
			30	40	50	60								
			36	48	59	71								
5			40	54	67	81	94							
			47	63	78	94	109							
			56	74	93	111	130							
6				78	97	116	136	155						
				90	112	134	156	178						
				107	133	160	186	213						
7				106	132	158	185	211	238					
				122	152	182	212	242	272					
				145	181	217	253	289	325					
8				138	173	207	242	276	311					
				159	198	237	276	315	354					
				189	236	283	331	378	425					
9				175	218	262	306	350	393					
				200	250	299	348	397	446					
				239	299	359	418	478	537					
10					270	324	378	432	486	540				
					308	368	429	489	550	610				
					369	442	516	589	663	736				
11					326	392	457	522	588	653				
					371	445	518	591	664	737				
					446	535	624	712	801	890				
12					388	466	544	622	699	777	855			
					441	528	615	702	789	875	962			
					530	636	742	847	953	1058	1164			
13						547	638	730	821	912	1003			
						619	721	822	924	1025	1127			
						746	870	994	1118	1242	1365			
14						635	740	846	952	1058	1164			
						716	834	952	1070	1187	1304			
						865	1009	1152	1296	1439	1583			
15						729	850	972	1093	1215	1336			
						821	956	1091	1226	1361	1495			
						993	1157	1322	1487	1651	1816			
16						829	967	1106	1244	1382	1520			
						933	1086	1240	1393	1546	1699			
						1129	1316	1504	1691	1878	2065			
17						936	1092	1248	1404	1560	1717	1873		
						1052	1225	1398	1570	1743	1915	2087		
						1274	1485	1697	1908	2119	2331	2542		
18						1049	1224	1399	1574	1749	1925	2100		
						1178	1371	1565	1758	1951	2144	2337		
						1428	1665	1902	2138	2375	2612	2849		
19						1169	1364	1559	1754	1949	2145	2340	2535	
						1310	1526	1742	1957	2172	2386	2601	2815	
						1590	1854	2118	2382	2646	2909	3173	3436	

Table 4.—*Dry weight in pounds for sweetgum bole wood, bole wood plus bark, and total tree—(Continued)*

	Total height in feet													
Dbh	10	20	30	40	50	60	70	80	90	100	110	120	130	140
inches	*pounds*													
20							1512	1728	1944	2160	**2376**	2593	**2809**	3025
							1689	1928	2166	2403	**2641**	2878	**3115**	3352
							2054	2346	2638	2930	**3222**	3514	**3806**	4098
21							1667	1905	**2143**	2382	2620	2858	3097	3335
							1860	2123	**2385**	2647	2908	3170	3431	3692
							2263	2586	**2908**	3230	3552	3873	4195	4517
22							1829	2091	2353	**2614**	2876	**3137**	3399	3661
							2039	2327	2615	**2902**	3189	**3475**	3761	4047
							2483	2837	3190	**3544**	3897	**4250**	4603	4955
23							2000	2286	**2571**	**2857**	**3143**	3429	3715	4001
							2227	2541	**2855**	**3169**	**3482**	3794	4107	4419
							2713	3100	**3486**	**3872**	**4258**	4643	5029	5415
24								2489	2800	3111	3423	**3734**	4046	4357
								2764	3106	3447	3787	**4128**	4468	4807
								3374	3795	4215	4635	**5055**	5474	5894
25								2701	3038	3376	3714	**4052**	**4390**	4728
								2997	3367	3737	4106	**4475**	**4843**	5211
								3660	4116	4572	5028	**5438**	**5938**	6394
26								2921	3287	3652	4017	4383	4748	5114
								3238	3638	4038	4437	4836	5234	5632
								3958	4451	4944	5436	5929	6421	6914
27								3150	3544	3939	**4333**	4727	5121	5515
								3489	3920	4351	**4781**	5210	5639	6068
								4267	4799	5330	**5861**	6392	6923	7454
28								3388	3812	4236	4660	5084	5508	5932
								3750	4213	4675	5137	5599	6060	6521
								4588	5160	5731	6302	6873	7444	8014
29								3635	4089	4544	4999	5454	5908	6363
								4019	4515	5011	5506	6001	6495	6989
								4920	5533	6146	6759	7371	7983	8595
30									4376	4863	5350	5836	6323	6810
									4828	5359	5888	6417	6946	7474
									5920	6576	7231	7886	8541	9196
31									4673	5193	5713	6232	6752	7272
									5152	5718	6283	6847	7411	7974
									6320	7020	7720	8419	9118	9817
32									4980	5534	6087	6641	7195	7749
									5486	6088	6690	7291	7891	8491
									6733	7479	8224	8969	9714	10459
33									5296	5885	6474	**7063**	7652	8241
									5830	6470	7109	**7748**	8386	9024
									7159	7952	8744	**9536**	10328	11120
34									5622	6247	6873	7498	8123	8749
									6184	6864	7542	8219	8896	9573
									7598	8439	9280	10121	10962	11802
35									5958	6621	7283	7946	8608	9271
									6549	7268	7987	8704	9421	10137
									8050	8941	9832	10723	11614	12504
36									6304	7005	7706	8407	9108	9809
									6925	7685	8444	9203	9961	10718
									8515	9458	10400	11343	12285	13226

[1] Tree weight from a 1-foot stump to the tree tip.

[2] The three vertical figures for each dbh give weights of bole wood first, bole wood plus bark second, and total tree (bole wood plus bark plus limbs excluding leaves) last.

[3] Boldface numbers span the range of the data.

Table 5.—*Regression statistics for predicting sweetgum bole volumes and weights using two bole diameter measurements and total height*[1]

Component	Average Y	b_0	b_1	Fit index[2]	$\hat{S}_e$[3]	C.V. percent[4]
			Volume *(cubic feet)*			
Bole wood	48.5	−5.917	0.99082	0.994	4.20*	8.9
Bole bark	5.8	−7.011	0.89596	0.941	1.34	23.0
Total bole	54.3	−5.651	0.97630	0.994	4.46*	8.2
			Green weight *(pounds)*			
Bole wood	3173	−1.925	1.01005	0.991	326*	10.3
Bole bark	293	−3.030	0.89055	0.945	65	22.1
Total bole	3466	−1.665	0.99328	0.993	326*	9.4
			Dry weight *(pounds)*			
Bole wood	1460	−2.787	1.01887	0.993	138*	9.5
Bole bark	163	−4.208	0.94870	0.939	39	23.9
Total bole	1623	−2.559	1.00699	0.994	142*	8.8

[1] Volumes and weights of trees from a 1-foot stump to the tree tip, using $\mathrm{Ln}(Y) = b_0 + b_1 \mathrm{Ln}(D \cdot D_{1/3} \cdot H)$; D = dbh, H = total tree height, $D_{1/3}$ = bole diameter outside bark at ⅓H.

[2] Fit index $= 1.0 - [\Sigma(Y - \hat{Y})^2 / \Sigma(Y - \bar{Y})^2]$, using untransformed values.

[3] $\hat{S}_e = [\Sigma(Y - \hat{Y})^2 / (n - 2)]^{1/2}$, using untransformed values.

[4] Coefficient of variation $= 100\, \hat{S}_e / \bar{Y}$.

*Significantly more precise by the F test than D^2H model; $\alpha = 0.05$.

Table 6.—*Regression statistics for predicting sweetgum bole volumes and weights using three bole diameter measurements and total height*[1]

Component	Average Y	b_0	b_1	Fit index[2]	$\hat{S}_e$[3]	C.V. percent[4]
			Volume *(cubic feet)*			
Bole wood	48.5	−6.566	1.00705	0.998	2.18+	4.5
Bole bark	5.8	−7.603	0.91105	0.936	1.40	24.0
Total bole	54.3	−6.291	0.99238	0.998	2.50+	4.6
			Green weight *(pounds)*			
Bole wood	3173	−2.585	1.02650	0.996	220+	6.9
Bole bark	293	−3.622	0.90575	0.939	68	23.3
Total bole	3466	−2.316	1.00957	0.997	205+	5.9
			Dry weight *(pounds)*			
Bole wood	1460	−3.451	1.03540	0.996	105+	7.2
Bole bark	163	−4.841	0.96511	0.933	41	25.2
Total bole	1623	−3.218	1.02349	0.996	107+	6.6

[1] Volumes and weights of trees from a 1-foot stump to the tree tip, using $\mathrm{Ln}(Y) = b_0 + b_1 \mathrm{Ln}[(D \cdot D_{1/2} + D^2_{1/4})H]$; D = dbh, H = total tree height, $D_{1/2}$ and $D_{1/4}$ = bole diameters outside bark at ½H and ¼H, respectively.

[2] Fit index $= 1.0 - [\Sigma(Y - \hat{Y})^2 / \Sigma(Y - \bar{Y})^2]$, using untransformed values.

[3] $\hat{S}_e = [\Sigma(Y - \hat{Y})^2 / (n - 2)]^{1/2}$, using untransformed values.

[4] Coefficient of variation $= 100\, \hat{S}_e / \bar{Y}$.

+ Significantly more precise by the F test than $D \cdot D_{1/3} \cdot H$ model; $\alpha = 0.05$.

Table 7.—*Local volume and weight equations for sweetgum*[1]

Component	Average Y	b_0	b_1	Fit index[2]	$\hat{S}_e$[3]	C.V. percent[4]
			Volume *(cubic feet)*			
Bole wood	48.5	–3.258	1.26184	0.956	11.10*	22.9
Bole bark	5.8	–4.601	1.14028	0.903	1.71	29.4
Total bole	54.3	–3.029	1.24314	0.957	12.12*	22.3
Total tree, excluding leaves	74.0	–2.884	1.25350	0.954	16.09*	21.7
			Green weight *(pounds)*			
Bole wood	3173	0.789	1.28600	0.952	773*	24.4
Bole bark	293	–0.635	1.13333	0.913	82	27.9
Total bole	3466	1.005	1.26454	0.954	810*	23.4
Total tree, excluding leaves	4719	1.145	1.27503	0.953	1057*	22.4
			Dry weight *(pounds)*			
Bole wood	1460	–0.049	1.29725	0.954	349*	23.9
Bole bark	163	–1.653	1.20710	0.893	52	31.7
Total bole	1623	0.148	1.28200	0.955	378*	23.3
Total tree, excluding leaves	2212	0.288	1.29232	0.956	484*	21.9

[1] Volumes and weights of trees from a 1-foot stump to the tree tip, using $\mathrm{Ln}(Y) = b_0 + b_1 \mathrm{Ln}(D^2)$; D = dbh.

[2] Fit index = $1.0 - [\Sigma(Y-\hat{Y})^2 / \Sigma(Y-\bar{Y})^2]$, using untransformed values.

[3] $\hat{S}_e = [\Sigma(Y-\hat{Y})^2 / (n-2)]^{1/2}$, using untransformed values.

[4] Coefficient of variation = $100\ \hat{S}_e / \bar{Y}$.

*Significantly less precise by the F test than D^2H model; $\alpha = 0.05$.

Table 8.—*Statistics for estimating confidence bounds for sweetgum predictions for the bole and total tree*

Independent variable – X	n	Mean of X	Corrected sum of squares for X[1]	$S_{y \cdot x}$ Standard error of estimate for tree components			
		Bole predictions			Wood	Bark	Total
$\mathrm{Ln}(D^2)$	54	4.762	154.074	Volume	0.1729	0.2668	0.1758
				Green weight	0.1957	0.2914	0.1900
				Dry weight	0.2010	0.3292	0.1954
$\mathrm{Ln}(D^2H)$	54	9.038	260.066	Volume	0.1213	0.2407	0.1260
				Green weight	0.1330	0.2718	0.1312
				Dry weight	0.1357	0.3129	0.1355
$\mathrm{Ln}(D \cdot D_{1/4} \cdot H)$	54	8.736	251.282	Volume	0.0601	0.2112	0.0621
				Green weight	0.0919	0.2414	0.0801
				Dry weight	0.1006	0.2764	0.0878
$\mathrm{Ln}[(D \cdot D_{1/2} + D^2_{1/4})H]$	54	9.238	243.351	Volume	0.0402	0.1986	0.0337
				Green weight	0.0856	0.2267	0.0647
				Dry weight	0.0977	0.2583	0.0753
		Total tree predictions				Total tree	
$\mathrm{Ln}(D^2)$	49	4.763	153.302	Volume		0.1898	
				Green weight		0.2024	
				Dry weight		0.2013	
$\mathrm{Ln}(D^2H)$	49	9.045	258.422	Volume		0.1632	
				Green weight		0.1652	
				Dry weight		0.1602	

[1] $\Sigma(X-\bar{X})^2$ in base e logarithmic units.

APPENDIX

Examples Using the Equations

In this section examples are presented to illustrate use of the equations. The following tabulation gives data used to illustrate equation use:

$D = 21.7$ in.
$H = 75.0$ ft.
$D_{1/4} = 15.5$ in.
$D_{1/3} = 14.8$ in.
$D_{1/2} = 11.5$ in.

Bole wood volume (V) is calculated using $X = D^2H$ and the parameter estimates from table 1 as follows:

$$\begin{aligned}
\mathrm{Ln}(V) &= b_0 = b_1\ \mathrm{Ln}(D^2H) \\
&= -6.048 + 0.97280\ \mathrm{Ln}\,(21.7 \times 21.7 \times 75.0) \\
&= -6.048 + 0.97280\ \mathrm{Ln}\,(35316.75) \\
&= -6.048 + 0.97280\,(10.472) \\
&= -6.048 + 10.187 \\
\mathrm{Ln}(V) &= 4.139
\end{aligned}$$

$V = e^{4.139}$; bole wood volume $= 62.7$ ft^3.

To calculate total green bole weight (W) using $X = D \cdot D_{1/3} \cdot H$ and the parameter estimates from table 5:

$$\begin{aligned}
\mathrm{Ln}(W) &= b_0 + b_1\ \mathrm{Ln}\,(D \cdot D_{1/3} \cdot H) \\
&= -1.665 + 0.99328\ \mathrm{Ln}\,(21.7 \times 14.8 \times 75.0) \\
&= -1.665 + 0.99328\ \mathrm{Ln}\,(24087.00) \\
&= -1.665 + 0.99328\,(10.089) \\
&= -1.665 + 10.021 \\
\mathrm{Ln}(W) &= 8.356
\end{aligned}$$

$W = e^{8.356}$; total bole green weight $= 4256$ lb.

To calculate bole dry weight (W) using $X = [(D \cdot D_{1/2} + D^2_{1/4})H]$ and the parameter estimates from table 6:

$$\begin{aligned}
\mathrm{Ln}(W) &= b_0 + b_1\ \mathrm{Ln}\,[(D \cdot D_{1/2} + D^2_{1/4})H] \\
&= -3.218 + 1.02349\ \mathrm{Ln}\,[(21.7 \times 11.5 + 15.5 \times 15.5) \times 75.0] \\
&= -3.218 + 1.02349\ \mathrm{Ln}\,[(249.55 + 240.25) \times 75.0] \\
&= -3.218 + 1.02349\ \mathrm{Ln}\,[489.80 \times 75.0] \\
&= -3.218 + 1.02349\ \mathrm{Ln}\,[36735.00] \\
&= -3.218 + 1.02349\,(10.511) \\
&= -3.218 + 10.758 \\
\mathrm{Ln}(W) &= 7.540
\end{aligned}$$

$W = e^{7.540}$; total bole dry weight $= 1882$ lb.

Merchantable bole estimates to, say, an 8-inch top are calculated using equation 3 to estimate the merchantable portion of the bole and then multiplying that proportion (R8) by the predicted bole estimate of interest. Letting $DI = 8.0$, $X = [(21.7 - 8.0)/21.7]$, or $X = 0.631$, and from (3):

$$\begin{aligned}
R8 &= [1.0 + \mathrm{EXP}\,(0.78495 + 10.76197\,(0.631) - 77.22807\,(0.631)^2 + 121.11402\,(0.631)^3 - 65.62841\,(0.631)^4)]^{-1} \\
&= [1.0 + \mathrm{EXP}\,(0.78495 + 10.76197\,(0.631) - 77.22807\,(0.39816) + 121.11402\,(0.25124) - 65.62841\,(0.15853))]^{-1} \\
&= [1.0 + \mathrm{EXP}\,(0.78495 + 6.79080 - 30.74913 + 30.42869 - 10.40407)]^{-1} \\
&= [1.0 + \mathrm{EXP}\,(-3.14876)]^{-1} \\
&= [1.0 + 0.04291]^{-1} \\
&= [1.04291]^{-1} \\
R8 &= 0.959.
\end{aligned}$$

Then bole wood volume to an 8-inch top (V8) can be calculated:

$$\begin{aligned}
V8 &= (R8)(\text{predicted total bole wood volume}) \\
&= (0.959)(62.7) \\
&= 60.1\ \text{ft}^3.
\end{aligned}$$

Of course, total bole volumes or weights can be calculated using any one of the three sets of parameter estimates given in tables 1, 5, or 6. Then any of these total bole calculations can be used with the estimate of merchantable proportion to calculate merchantable bole values. The choice of which set of equations to use is left to the user, who must balance inventory precision against inventory cost.

Schlaegel, Bryce E. Sweetgum volume and weight tables. Res. Pap. SO-204. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1984. 14 p.

A sample of 54 trees from the Mississippi Delta is used to construct volume and weight tables for sweetgum.

Additional keywords: *Liquidambar styraciflua,* merchantable bole estimates, biomass.

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Sugarberry Volume and Weight Tables

Bryce E. Schlaegel

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SUMMARY

Volume and weight tables were constructed from a 121-tree sample of sugarberry *(Celtis laevigata* Willd.) taken in the Mississippi Delta. The tables present cubic-foot volume, green weight, and dry weight of bole wood, bole wood plus bark, and total tree excluding leaves above a 1-foot stump as predicted from the allometric model $\mathrm{Ln}\ Y = b_0 + b_1 \mathrm{Ln}(D^2H)$. Merchantable bole volume and weight estimates can be made to any outside bark diameter limit. More precise bole estimates can be obtained from equations using upper bole diameters taken at relative heights of 25, 33, and 50 percent of total tree height.

Sugarberry Volume and Weight Tables

Bryce E. Schlaegel

INTRODUCTION

Sugarberry *(Celtis laevigata* Willd.) grows on bottomlands of the Piedmont and Coastal Plain of the southern United States from southeastern Virginia, south to southern Florida, then west along the Gulf Coast into Texas, north to western Oklahoma, Missouri, southern Illinois and Indiana, and western Kentucky (Little 1979) (fig. 1). It is most commonly found on clay soils of broad flats or shallow sloughs within the flood plains of major southern rivers but thrives on various types of soils. This is a slow growing species, with trees reaching 80 feet in height and 20 inches in dbh.

In recent years there has been considerable demand for volume and weight tables for bottomland hardwood species. This paper is the fourth in a series of six giving both volume and weight tables for some of the major bottomland hardwood species. The other five species in the series are willow oak *(Quercus phellos* L.) (Schlaegel 1981), Nuttall oak *(Q. nuttallii* Palmer) (Schlaegel and Willson 1983), overcup oak *(Q. lyrata* Walt.) (Schlaegel 1984a), sweetgum *(Liquidambar styraciflua* L.) (Schlaegel 1984b), and green ash *(Fraxinus pennsylvanica* Marsh.) (Schlaegel 1984c).

METHODS

The data were collected from 15 natural bottomland hardwood stands in west-central Mississippi. Stands were either even- or uneven-aged with a mixed species composition. Each stand was measured for species composition and diameter distribution; 121 trees, ranging in dbh from 1 through 22 inches, were chosen for destructive sampling. Growing stock trees with healthy crowns and no visible signs of disease or decay were selected from both the overstory and understory. When available, three trees were selected from each 1-inch diameter class. Cutting was done throughout the year.

Stump height and total height were measured on each felled sample tree. Disks about 1-inch thick were cut from the bole at regular intervals from the stump to the top of the tree. These were then sealed in separate polyethylene bags for laboratory determination of moisture content and specific gravity. The first disk was at stump height and the remainder at 5-foot intervals measured from ground level for trees 5 inches dbh and larger and at 3-foot intervals for trees smaller than 5 inches dbh. All limbs, including leaves, were weighed on 115 of the trees.

In the laboratory, both wood and bark moisture content and specific gravity were determined as follows:

1. Wood and bark were separated with a hammer and chisel.
2. Each component was weighed green.
3. Both wood and bark were soaked in water for at least an hour to ensure complete swelling.
4. Volumes were obtained by immersion (Heinrichs and Lassen 1970).
5. Wood and bark were dried in a forced-air oven at 105°C for at least 48 hours.
6. Wood or bark moisture content = $$\frac{\text{green weight} - \text{ovendry weight}}{\text{ovendry weight}}.$$
7. Specific gravity = $$\frac{\text{ovendry wood or bark weight (g)}}{\text{green wood or bark volume (cm}^3\text{)}}.$$

Average tree moisture content and specific gravity were calculated from weighted averages of the disk moisture contents and specific gravities; each disk specific gravity or moisture content was weighted by its squared average diameter.

Taper functions (Schlaegel 1981, Schlaegel and Willson 1983) of the form

$$Y = b_1(X^1 - 1) + b_2(X^2 - 1) + \ldots + b_p(X^p - 1)$$

where

Y = d/D,

d = diameter at height h on the bole,

D = dbh,

X = h/H,

h = height from ground to a specific measurement point,

H = total height,

b_i = coefficients estimated for each tree by linear regression; $i = 1, 2, \ldots p$; $4 \leq p \leq 7$,

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were calculated for each tree, both inside and outside bark. Cubic-foot volumes were obtained for each tree by integrating the taper function to heights of specific top diameters to obtain both total and merchantable bole volumes. Bole green and dry weights were calculated from estimated tree volume and weighted average tree density and moisture content.

Allometric regression equations were used to estimate volume, green weight, and dry weight of bole wood, bole wood plus bark, and bole wood plus bark plus limbs.

RESULTS

Characteristics of the trees used in this study are:

	Average	Range
Age *(years)*	38	8 – 156
Dbh *(in)*	8.1	0.8 – 21.9
Total height *(ft)*	54	11 – 92
Wood moisture content *(percent)*	80	56 – 97
Bark moisture content *(percent)*	74	44 – 201
Wood specific gravity	0.481	0.330 – 0.572
Bark specific gravity	0.579	0.283 – 0.782
Wood + bark green density *(lb/ft)*	54.63	34.88 – 64.53
Wood + bark dry density *(lb/ft))*	30.54	20.62 – 34.72
Wood + bark moisture content *(percent)*	79	57 – 101
Wood + bark specific gravity	0.489	0.330 – 0.556

Individual tree volumes and weights were fitted to the allometric model:

$$\mathrm{Ln}(Y) = b_0 + b_1\,\mathrm{Ln}(D^2H) \tag{1}$$

where

Y = the volume or weight variable of interest,

Ln is a natural logarithm;

b_0 and b_1 are coefficients estimated from the data.

Estimates of the coefficients b_0 and b_1 are presented in table 1 for predicting cubic foot volume and green and dry weight of bole wood, bole bark, total bole, and total tree excluding leaves. Additional statistics presented are the component average, fit index, regression standard error of estimate ($\hat{S}_e$) based on residuals after converting to actual units, and coefficient of variation (C.V.) of predictions in arithmetic units. Fit index, which is similar to R^2, is used to judge equation efficiency when the dependent varia-

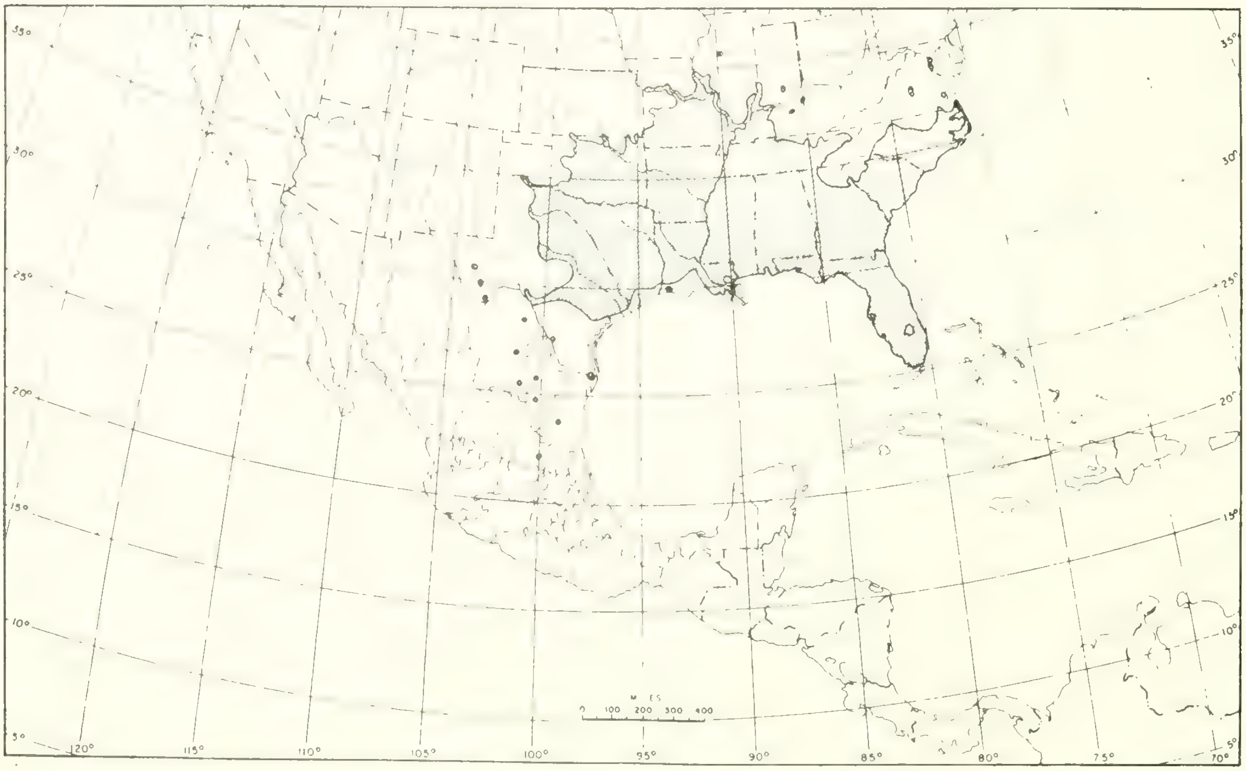

Figure 1.—*The range of sugarberry (Fowells 1965). (F-506584)*

ble has been transformed (Farrar 1978) and is calculated in untransformed units from the total and residual sums of squares.[1] The fit index and R^2 are equal when a simple linear regression analysis is performed on an untransformed dependent variable.

Fit indices range from 0.792 for dry bark weight to 0.988 for bole wood volume. A fit index of 1.0 indicates that predictions can be made without error with the data used to fit the model; a value close to 1 is desirable. Coefficients of variation, which are indices of relative precision of prediction, range from 66.1 percent for dry bark weight to 13.8 percent for bole wood volume.

Using measures of individual tree dbh and total height, estimates can be made using table 1 for tree volume (given in table 2), green weight (given in table 3), and dry weight (given in table 4) for bole wood, bole wood plus bark, and for bole wood plus bark plus limbs excluding leaves.

The equations were developed using trees from a limited geographic range compared to the total range. Therefore, predictions may be less precise when the equations are applied in other parts of the range. Using an upper bole diameter measurement in addition to dbh as described later should alleviate this problem.

MERCHANTABLE BOLE ESTIMATES

The merchantable bole is defined as the tree bole from a 1-foot stump to a specified top diameter, ignoring limbs. Merchantable bole volume or weight can be expressed as a proportion of the total bole by a generalized form of the logistic model

$$R_I = (1.0 + e^{f(X)})^{-1} \qquad (2)$$

where

R_I = ratio of merchantable bole volume or weight to total bole volume or weight, where I = top outside bark diameter of merchantable bole,

$X = (D - d_I)/D$,

D = tree dbh outside bark, and

d_I = outside bark top diameter.

For a specific top diameter, the ratio of merchantable bole to total bole is the same for volume, green weight, dry weight, and inside and outside bark (Schlaegel and Willson 1983).

Model 2 was fitted to the overcup oak data for trees ≥4.6 inches dbh, with $f(X) = b_0 + b_1X + b_2X^2 + b_3X^3 + b_4X^4$. Inverting (2) and taking the natural logarithm results in

$$\mathrm{Ln}\left(\frac{1 - R_I}{R_I}\right) = b_0 + b_1X + b_2X^2 + b_3X^3 + b_4X^4;$$

this was solved using multiple linear regression techniques giving:

$$R_I = [1.0 + \mathrm{EXP}\,(1.58529 + 1.83111\,X - 51.10565\,X^2 + 91.90861\,X^3 - 54.30496\,X^4)]^{-1} \qquad (3)$$

with fit index = 0.951 and $\hat{S}_e = 0.052$; EXP is the base of the natural logarithm and equals 2.71828.

Volume or weight to any top diameter (V_I) is found by multiplying the ratio estimate obtained from (3) by a total bole volume or weight estimate from either table 2, 3, or 4:

$$V_I = R_I \cdot V_T,$$

where V_T is the total bole volume or weight of interest.

IMPROVED TOTAL BOLE ESTIMATES

The precision of the merchantable bole estimate depends upon accuracy in measuring total bole. Total bole estimates can be significantly improved by measuring one or two additional diameters. Tables 5 and 6 give regression statistics for total bole volume and weight under two different model forms:

$$\mathrm{Ln}(Y) = b_0 + b_1\,\mathrm{Ln}(D \cdot D_{1/3} \cdot H) \qquad (4)$$

and

$$\mathrm{Ln}(Y) = b_0 + b_1\,\mathrm{Ln}[(D \cdot D_{1/2} + D^2_{1/4}) \cdot H] \qquad (5)$$

where D, H, and Y are as defined previously, and $D_{1/3}$, $D_{1/2}$, and $D_{1/4}$ are diameters measured outside the bark at one-third, one-half, and one-fourth the total height.

Statistics from tables 5 and 6 show the significant ($\alpha = 0.05$) improvement over the previous D^2H equations of table 1. Measuring one additional diameter at one-third the tree height reduces $\hat{S}_e$ for bole wood volume, total bole volume, green wood and total bole weight, and total dry bole weight by 31, 45, 18, 32, and 30 percent, respectively. Other standard errors are reduced but not significantly.

Measuring two upper bole diameters at one-fourth and one-half total height will result in further significant increases in precision. Improvements over the D^2H model range from 17 to 53 percent for bole wood and total bole and from 6 to 9 percent for bark.

Taking additional bole measures means a higher inventory cost, since more time will be spent at each tree, but most of the inventory cost is in traveling to the candidate tree. Data presented in this paper allow total and merchantable bole estimates to be made with high reliability. Each user has to decide when increased precision is needed and whether the need offsets the higher cost.

LOCAL VOLUME TABLES

There are many occasions when the only tree variable available is dbh, or perhaps only a rough estimate of tree volume or weight is needed. In these cases a local volume table will suffice. Table 7 gives the statistics needed for estimating by the local volume table technique. However, it must be realized that estimation precision may be considerably lessened. The local volume or weight model is

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[1] $FI = \{1 - [\Sigma(Y_i - \hat{Y}_i)^2] / [\Sigma(Y_i - \overline{Y})^2]\}$

$$\mathrm{Ln}(Y) = b_0 + b_1\,\mathrm{Ln}(D^2). \qquad (6)$$

Precision is significantly ($\alpha = 0.05$) reduced when only dbh is used to predict bole wood, total bole, and total tree. But bark estimates are more precise using the local equations.

CALCULATING CONFIDENCE LIMITS

Confidence limits ($(1 - \alpha)$ percent confidence limits) of individual predictions can be calculated using statistics presented in table 8. Clark et al. (1980) used the technique of Land (1972) to estimate approximate confidence limits for lognormal means of scarlet oak:

$$Y_{U.L.} = \mathrm{EXP}\left\{ \mathrm{Ln}(Y) \pm Z_{\alpha/2}\left[S^2_{y\cdot x}\left[\frac{1}{n} + \frac{(X - \bar{X})^2}{\Sigma(X - \bar{X})^2}\right] + \frac{S^4_{y\cdot x}}{2(n+1)} \right]^{1/2} \right\}$$

where:

$Y_{U.L.}$ = upper and lower limits for Y,

EXP = base of natural logarithm; EXP = e = 2.71828,

Y = predicted volume or weight of component,

$Z_{\alpha/2}$ = value for the upper $\alpha/2$ percentage point from the standard normal table,

$S_{y\cdot x}$ = standard error of estimate for prediction equation,

n = number of observations used to develop the equation,

$\bar{X}$ = sample mean of Ln(X),

$\Sigma(X - \bar{X})^2$ = corrected sum of squares for Ln(X),

X = $\mathrm{Ln}(D^2H)$; D = dbh and H = total height of tree for which Y is predicted.

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Table 1.—*Regression statistics for predicting sugarberry tree volumes and weights using dbh and total height*[1]

Component	Average Y	b_0	b_1	Fit index[2]	$\hat{S}_e$[3]	C.V. percent[4]
			Volume *(cubic feet)*			
Bole wood	13.1	−5.862	0.95323	0.988	1.81	13.8
Bole bark	1.2	−7.223	0.83390	0.825	0.67	56.9
Total bole	14.3	−5.649	0.93856	0.986	2.07	14.5
Total tree, excluding leaves	21.1	−5.484	0.95437	0.962	5.28	25.0
			Green weight *(pounds)*			
Bole wood	708	−1.892	0.95566	0.984	111	15.6
Bole bark	78	−3.332	0.86691	0.806	48	62.2
Total bole	786	−1.683	0.94340	0.983	126	16.1
Total tree, excluding leaves	1158	−1.515	0.95778	0.963	283	24.4
			Dry weight *(pounds)*			
Bole wood	393	−2.474	0.95535	0.982	64	16.4
Bole bark	48	−4.067	0.89204	0.792	32	66.1
Total bole	441	−2.287	0.94643	0.984	70	15.8
Total tree, excluding leaves	652	−2.118	0.96116	0.963	160	24.5

[1] Volumes and weights of trees from a 1-foot stump to the tree tip, using $\mathrm{Ln}(Y) = b_0 + b_1 \mathrm{Ln}(D^2H)$; D = dbh, H = total tree height.

[2] Fit index $= 1.0 - [\Sigma(Y - \hat{Y})^2 / \Sigma(Y - \overline{Y})^2]$, using untransformed values.

[3] $\hat{S}_e = [\Sigma(Y - \hat{Y})^2 / (n - 2)]^{1/2}$, using untransformed values.

[4] Coefficient of variation $= 100\ \hat{S}_e / \overline{Y}$.

Table 2.—*Cubic-foot volume for sugarberry bole wood, bole wood plus bark, and total tree*[1]

	Total height in feet									
Dbh	10	20	30	40	50	60	70	80	90	100
inches	*cubic feet*									
1	0.03[2]	0.05								
	0.03[3]	0.06								
	0.04	0.07								
2	0.10	0.19	0.27							
	0.11	0.22	0.31							
	0.14	0.27	0.40							
3		0.40	0.59	0.78						
		0.46	0.67	0.88						
		0.59	0.87	1.14						
4		0.70	1.02	1.35	1.67	1.98				
		0.79	1.16	1.52	1.87	2.22				
		1.02	1.50	1.98	2.45	2.91				
5			1.57	2.06	2.55	3.03				
			1.76	2.30	2.84	3.37				
			2.30	3.03	3.75	4.46				
6				2.92	3.61	4.29	4.97			
				3.24	4.00	4.75	5.48			
				4.29	5.31	6.32	7.32			
7				3.91	4.84	5.76	6.67	7.58		
				4.33	5.34	6.34	7.32	8.30		
				5.76	7.13	8.48	9.82	11.20		
8				5.05	6.24	7.43	8.60	9.77		
				5.57	6.86	8.14	9.41	10.70		
				7.43	9.19	10.90	12.70	14.40		
9					7.81	9.30	10.8	12.2		
					8.56	10.20	11.7	13.3		
					11.50	13.70	15.9	18.0		
10					9.55	11.4	13.2	14.9	16.7	
					10.40	12.4	14.3	16.2	18.1	
					14.10	16.7	19.4	22.0	24.7	
11					11.5	13.6	15.8	17.9	20.1	
					12.5	14.8	17.1	19.4	21.7	
					16.9	20.1	23.3	26.4	29.6	
12					13.5	16.1	18.6	21.2	23.7	
					14.7	17.4	20.1	22.8	25.5	
					19.9	23.7	27.5	31.2	34.9	
13					15.7	18.7	21.7	24.7	27.6	
					17.1	20.3	23.4	26.5	29.6	
					23.2	27.6	32.0	36.4	40.7	
14						21.6	25.0	28.4	31.8	
						23.3	26.9	30.5	34.1	
						31.8	36.9	41.9	46.9	
15						24.6	28.5	32.4	36.2	
						26.5	30.6	34.7	38.8	
						36.3	42.1	47.8	53.5	
16						27.8	32.2	36.6	41.0	45.3
						29.9	34.6	39.2	43.8	48.3
						41.1	47.6	54.1	60.5	66.9
17						31.3	36.2	41.1	46.0	50.9
						33.5	38.7	43.9	49.0	54.1
						46.1	53.4	60.7	67.9	75.1
18						34.9	40.4	45.8	51.3	56.7
						37.3	43.1	48.9	54.6	60.3
						51.4	59.6	67.7	75.7	83.8

Table 2.—*Cubic-foot volume for sugarberry bole wood, bole wood plus bark, and total tree—(Continued)*

	Total height in feet									
Dbh	10	20	30	40	50	60	70	80	90	100
inches	*cubic feet*									
19						38.6	44.8	50.8	**56.9**	62.9
						41.3	47.7	54.1	**60.4**	66.7
						57.0	66.1	75.1	**84.0**	92.8
20						42.6	49.4	56.0	**62.7**	69.3
						45.5	52.5	59.6	**66.5**	73.4
						62.9	72.9	82.8	**92.6**	102.0
21						**46.8**	54.2	61.5	68.8	76.1
						49.8	57.6	65.3	72.9	80.5
						69.0	80.0	90.9	102.0	112.0
22						51.1	59.2	67.2	**75.2**	83.2
						54.4	62.8	71.2	**79.6**	87.8
						75.4	87.4	99.3	**111.0**	123.0
23						55.6	64.4	73.2	81.9	90.5
						59.1	68.3	77.4	86.5	95.5
						82.1	95.2	108.0	121.0	134.0
24						60.3	69.9	79.3	88.8	98.2
						64.0	74.0	83.9	93.7	103.0
						89.1	103.0	117.0	131.0	145.0
25						65.2	75.5	85.8	96.0	106
						69.1	79.9	90.6	101.0	112
						96.3	112.0	127.0	142.0	157
26						70.3	81.4	92.4	103	114
						74.4	86.0	97.5	109	120
						104.0	120.0	137.0	153	169

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[1] Tree volume from a 1-foot stump to the tree tip.

[2] The three vertical figures for each dbh give volumes of bole wood first, bole wood plus bark second, and total tree (bole wood plus bark plus limbs excluding leaves) last.

[3] Boldface numbers span the range of the data.

Table 3.—*Green weight in pounds for sugarberry bole wood, bole wood plus bark, and total tree*[1]

	Total height in feet									
Dbh	10	20	30	40	50	60	70	80	90	100
inches	*pounds*									
1	**1.4**[2]	**2.6**								
	1.6[3]	**3.1**								
	2.0	**3.9**								
2	**5.1**	**9.9**	**15**							
	6.0	**11.6**	**17**							
	7.5	**14.6**	**22**							
3		**22**	**32**	**42**						
		25	**37**	**48**						
		32	**47**	**62**						
4		37	**55**	**72**	**90**	107				
		43	**63**	**82**	**102**	121				
		55	**81**	**107**	**133**	158				
5			84	**111**	**137**	164				
			96	**126**	**155**	184				
			125	**164**	**203**	242				
6				157	**195**	232	268			
				177	**219**	260	301			
				233	**288**	343	398			
7				211	**261**	**311**	**360**	410		
				237	**293**	**348**	**402**	456		
				313	**387**	**461**	**535**	608		
8				273	337	**402**	**465**	529		
				305	377	**447**	**517**	587		
				404	500	**596**	**691**	785		

Table 3.—*Green weight in pounds for sugarberry bole wood, bole wood plus bark, and total tree—(Continued)*

	Total height in feet									
Dbh	10	20	30	40	50	60	70	80	90	100
inches	*pounds*									
9					422	**503**	**583**	662		
					470	**559**	**646**	733		
					627	**747**	**865**	983		
10					517	**615**	**713**	**810**	906	
					574	**681**	**788**	**894**	999	
					767	**913**	**1059**	**1203**	1347	
11					620	**738**	**855**	**972**	1087	
					687	**816**	**943**	**1070**	1196	
					921	**1096**	**1271**	**1444**	1617	
12					732	**872**	**1010**	**1147**	1284	
					809	**961**	**1112**	**1261**	1409	
					1088	**1295**	**1501**	**1706**	1910	
13					853	**1016**	**1177**	**1337**	1496	
					941	**1118**	**1293**	**1466**	1639	
					1268	**1510**	**1750**	**1989**	2226	
14						1170	**1356**	**1540**	1724	
						1286	**1487**	**1686**	1885	
						1740	**2017**	**2292**	2566	
15						1335	1547	**1758**	1967	
						1464	1694	**1921**	2147	
						1986	2302	**2616**	2929	
16						1510	1750	**1988**	2225	2461
						1654	1913	**2170**	2425	2678
						2247	2605	**2960**	3314	3666
17						1696	**1965**	**2233**	**2499**	2763
						1854	**2145**	**2433**	**2718**	3003
						2524	**2926**	**3325**	**3722**	4117
18						1892	**2192**	**2490**	**2787**	3082
						2066	**2389**	**2710**	**3028**	3344
						2816	**3264**	**3710**	**4153**	4594
19						2098	2431	2761	**3090**	3418
						2287	2645	3001	**3353**	3704
						3124	3621	4114	**4606**	5095
20						2314	2681	3046	**3409**	3770
						2520	2914	3306	**3694**	4080
						3446	3994	4539	**5081**	5621
21						**2540**	2943	3344	3742	4138
						2763	3195	3624	4050	4473
						3784	4386	4984	5579	6172
22						2776	3217	3654	**4090**	4523
						3016	3488	3957	**4422**	4884
						4136	4794	5448	**6099**	6747
23						3022	3502	3979	4452	4924
						3280	3794	4303	4809	5311
						4504	5221	5933	6641	7346
24						3278	3799	4316	4830	5341
						3554	4111	4663	5211	5755
						4887	5664	6437	7205	7970
25						3544	4107	4666	5222	5775
						3839	4440	5036	5628	6216
						5284	6125	6960	7791	8619
26						3820	4427	5029	5628	6224
						4134	4781	5423	6060	6694
						5696	6602	7503	8399	9291

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[1] Tree weight from a 1-foot stump to the tree tip.

[2] The three vertical figures for each dbh give weights of bole wood first, bole wood plus bark second, and total tree (bole wood plus bark plus limbs excluding leaves) last.

[3] Boldface numbers span the range of the data.

Table 4.—*Dry weight in pounds for sugarberry bole wood, bole wood plus bark, and total tree*[1]

	Total height in feet									
Dbh	10	20	30	40	50	60	70	80	90	100
inches	*pounds*									
1	0.8[2]	1.5								
	0.9[3]	1.7								
	1.1	2.1								
2	2.9	5.5	8.2							
	3.3	6.4	9.4							
	4.2	8.1	12.0							
3		12	18	23						
		14	20	27						
		18	26	34						
4		21	31	40	50	60				
		24	35	46	57	67				
		31	45	60	74	88				
5			47	62	77	91				
			53	70	87	103				
			70	92	114	136				
6				88	109	129	150			
				99	122	145	168			
				131	162	193	224			
7				118	146	173	201	228		
				133	164	195	225	256		
				176	218	259	301	342		
8				152	188	224	259	295		
				171	211	251	290	329		
				227	281	335	389	442		
9					235	280	325	369		
					264	313	362	411		
					353	420	487	554		
10					288	343	397	451	505	
					322	382	442	502	561	
					432	515	597	679	760	
11					346	411	476	541	606	
					385	458	530	601	672	
					519	618	717	815	913	
12					408	486	563	639	715	
					454	540	625	709	793	
					613	731	847	964	1079	
13					475	576	656	745	834	
					529	628	727	825	922	
					715	852	988	1124	1259	
14						652	755	858	960	
						723	837	949	1061	
						983	1140	1296	1451	
15						744	862	979	1096	
						824	953	1082	1209	
						1122	1301	1480	1657	
16						841	975	1108	1240	1371
						931	1077	1222	1366	1510
						1270	1473	1675	1876	2076
17						945	1095	1244	1392	1539
						1044	1208	1371	1532	1693
						1427	1655	1882	2108	2332
18						1054	1221	1387	1552	1717
						1163	1346	1527	1708	1887
						1593	1848	2101	2353	2603

Table 4.—*Dry weight in pounds for sugarberry bole wood, bole wood plus bark, and total tree—(Continued)*

Dbh	Total height in feet									
	10	20	30	40	50	60	70	80	90	100
inches	*pounds*									
19						1168	1354	1538	**1721**	1904
						1289	1491	1692	**1892**	2090
						1768	2050	2331	**2610**	2888
20						1289	1493	1696	**1899**	2100
						1420	1643	1865	**2084**	2303
						1951	2263	2572	**2881**	3188
21						**1415**	1639	1862	2084	2305
						1558	1802	2045	2286	2526
						2143	2485	2825	3164	3501
22						1546	1792	2035	**2278**	2519
						1701	1968	2233	**2497**	2758
						2343	2717	3090	**3460**	3829
23						1683	1950	2216	2480	2742
						1850	2141	2429	2716	3000
						2552	2960	3365	3769	4170
24						1826	2116	2403	2690	2975
						2005	2320	2633	2944	3252
						2770	3212	3652	4090	4526
25						1974	2287	2598	2908	3216
						2167	2507	2845	3180	3513
						2996	3474	3950	4424	4895
26						2128	2465	2801	3134	3466
						2334	2700	3064	3425	3784
						3231	3747	4260	4770	5279

[1] Tree weight from a 1-foot stump to the tree tip.

[2] The three vertical figures for each dbh give weights of bole wood first, bole wood plus bark second, and total tree (bole wood plus bark plus limbs excluding leaves) last.

[3] Boldface numbers span the range of the data.

Table 5.—*Regression statistics for predicting sugarberry bole volumes and weights using two bole diameter measurements and total height*[1]

Component	Average Y	b_0	b_1	Fit index[2]	$\hat{S}_e$[3]	C.V. percent[4]
	Volume *(cubic feet)*					
Bole wood	13.1	−5.802	0.98071	0.994	1.24*	9.5
Bole bark	1.2	−7.185	0.85923	0.847	0.62	53.2
Total bole	14.3	−5.591	0.96572	0.996	1.12*	7.9
	Green weight *(pounds)*					
Bole wood	708	−1.834	0.98331	0.989	91*	12.9
Bole bark	78	−3.295	0.89339	0.829	45	58.3
Total bole	786	−1.627	0.97083	0.992	86*	11.0
	Dry weight *(pounds)*					
Bole wood	393	−2.415	0.98301	0.986	58	14.7
Bole bark	48	−4.030	0.91937	0.816	30	62.2
Total bole	441	−2.231	0.97398	0.992	49*	11.2

[1] Volumes and weights of trees from a 1-foot stump to the tree tip, using $\mathrm{Ln}(Y) = b_0 + b_1 \mathrm{Ln}(D \cdot D_{1/3} \cdot H)$; D = dbh, H = total tree height, $D_{1/3}$ = bole diameter outside bark at ⅓H.

[2] Fit index = $1.0 - [\Sigma(Y - \hat{Y})^2 / \Sigma(Y - \bar{Y})^2]$, using untransformed values.

[3] $\hat{S}_e = [\Sigma(Y - \hat{Y})^2 / (n - 2)]^{1/2}$, using untransformed values.

[4] Coefficient of variation = $100\ \hat{S}_e / \bar{Y}$.

*Significantly more precise by the F test than D^2H model; $\alpha = 0.05$.

Table 6.—*Regression statistics for predicting sugarberry bole volumes and weights using three bole diameter measurements and total height*[1]

Component	Average Y	b_0	b_1	Fit index[2]	$\hat{S}_e$[3]	C.V. percent[4]
			Volume *(cubic feet)*			
Bole wood	13.1	−6.513	1.00617	0.996	1.00*	7.7
Bole bark	1.2	−7.812	0.88195	0.852	0.61	52.3
Total bole	14.3	−6.292	0.99084	0.999	0.64*	4.5
			Green weight *(pounds)*			
Bole wood	708	−2.547	1.00883	0.991	83+	11.8
Bole bark	78	−3.946	0.91693	0.835	45	57.3
Total bole	786	−2.331	0.99606	0.995	71*	9.0
			Dry weight *(pounds)*			
Bole wood	393	−3.128	1.00857	0.988	53+	13.6
Bole bark	48	−4.701	0.94369	0.821	30	61.3
Total bole	441	−2.938	0.99936	0.995	40*	9.1

[1] Volumes and weights of trees from a 1-foot stump to the tree tip, using $\mathrm{Ln}(Y) = b_0 + b_1 \mathrm{Ln}[(D \cdot D_{1/2} + D^2_{1/4})H]$; D = dbh, H = total tree height, $D_{1/2}$ and $D_{1/4}$ = bole diameters outside bark at ½H and ¼H, respectively.

[2] Fit index = $1.0 - [\Sigma(Y - \hat{Y})^2 / \Sigma(Y - \bar{Y})^2]$, using untransformed values.

[3] $\hat{S}_e = [\Sigma(Y - \hat{Y})^2 / (n - 2)]^{1/2}$, using untransformed values.

[4] Coefficient of variation = $100\ \hat{S}_e / \bar{Y}$.

+ Significantly more precise by the F test than $D \cdot D_{1/3} \cdot H$ model; $\alpha = 0.05$.

* Significantly more precise by the F test than D^2H model; $\alpha = 0.05$.

Table 7.—*Local volume and weight equations for sugarberry*[1]

Component	Average Y	b_0	b_1	Fit index[2]	$\hat{S}_e$[3]	C.V. percent[4]
			Volume *(cubic feet)*			
Bole wood	13.1	−3.179	1.23777	0.934	4.18*	31.9
Bole bark	1.2	−4.904	1.08668	0.880	0.56+	47.1
Total bole	14.3	−3.011	1.21917	0.950	3.95*	27.7
Total tree, excluding leaves	21.1	−2.819	1.24272	0.949	6.08	28.8
			Green weight *(pounds)*			
Bole wood	708	0.796	1.24113	0.919	249*	35.2
Bole bark	78	−0.916	1.12891	0.861	41+	52.6
Total bole	786	0.967	1.22559	0.939	241*	30.7
Total tree, excluding leaves	1158	1.159	1.24723	0.946	344*	29.7
			Dry weight *(pounds)*			
Bole wood	393	0.217	1.24031	0.909	146*	37.1
Bole bark	48	−1.591	1.16320	0.849	27+	56.2
Total bole	441	0.373	1.22941	0.934	140*	31.7
Total tree, excluding leaves	652	0.566	1.25157	0.941	202*	30.9

[1] Volumes and weights of trees from a 1-foot stump to the tree tip, using $\mathrm{Ln}(Y) = b_0 + b_1 \mathrm{Ln}(D^2)$; D = dbh.

[2] Fit index = $1.0 - [\Sigma(Y - \hat{Y})^2 / \Sigma(Y - \bar{Y})^2]$, using untransformed values.

[3] $\hat{S}_e = [\Sigma(Y - \hat{Y})^2 / (n - 2)]^{1/2}$, using untransformed values.

[4] Coefficient of variation = $100\ \hat{S}_e / \bar{Y}$.

+ Significantly more precise by the F test than D^2H model; $\alpha = 0.005$.

* Significantly less precise by the F test than D^2H model; $\alpha = 0.05$.

Table 8.—*Statistics for estimating confidence bounds for sugarberry predictions for the bole and total tree*

Independent variable – X	n	Mean of X	Corrected sum of squares for X[1]	$S_{y \cdot x}$ Standard error of estimate for tree components			
	Bole predictions				Wood	Bark	Total
$\text{Ln}(D^2)$	121	3.556	354.483	Volume	0.1915	0.3029	0.1775
				Green weight	0.2053	0.3616	0.1983
				Dry weight	0.2178	0.3408	0.2017
$\text{Ln}(D^2H)$	121	7.422	600.271	Volume	0.1306	0.3188	0.1255
				Green weight	0.1548	0.3690	0.1560
				Dry weight	0.1617	0.3644	0.1574
$\text{Ln}(D \cdot D_{1/3} \cdot H)$	121	7.148	568.328	Volume	0.0847	0.2889	0.0716
				Green weight	0.1143	0.3396	0.1119
				Dry weight	0.1227	0.3315	0.1116
$\text{Ln}[(D \cdot D_{1/2} + D^2_{1/4})H]$	121	7.672	540.282	Volume	0.0643	0.2791	0.0423
				Green weight	0.1004	0.3315	0.0964
				Dry weight	0.1079	0.3215	0.0929
	Total tree predictions					Total tree	
$\text{Ln}(D^2)$	115	3.491	344.521	Volume		0.1540	
				Green weight		0.1774	
				Dry weight		0.1786	
$\text{Ln}(D^2H)$	115	7.339	584.102	Volume		0.1555	
				Green weight		0.1800	
				Dry weight		0.1799	

[1] $\Sigma(X - \bar{X})^2$ in base e logarithmic units.

APPENDIX

Examples Using the Equations

In this section examples are presented to illustrate use of the equations. The following tabulation gives data used to illustrate equation use:

$D = 21.7$ in.
$H = 75.0$ ft.
$D_{1/4} = 15.5$ in.
$D_{1/3} = 14.8$ in.
$D_{1/2} = 11.5$ in.

Bole wood volume (V) is calculated using $X = D^2H$ and the parameter estimates from table 1 as follows:

$$
\begin{aligned}
\mathrm{Ln}(V) &= b_0 + b_1 \,\mathrm{Ln}(D^2H) \\
&= -5.862 + 0.95323 \,\mathrm{Ln}\,(21.7 \times 21.7 \times 75.0) \\
&= -5.862 + 0.95323 \,\mathrm{Ln}\,(35316.75) \\
&= -5.862 + 0.95323\,(10.472) \\
&= -5.862 + 9.982 \\
\mathrm{Ln}(V) &= 4.120
\end{aligned}
$$

$V = e^{4.120}$; bole wood volume $= 61.6$ ft^3.

To calculate total green bole weight (W) using $X = D \cdot D_{1/3} \cdot H$ and the parameter estimates from table 5:

$$
\begin{aligned}
\mathrm{Ln}(W) &= b_0 + b_1 \,\mathrm{Ln}\,(D \cdot D_{1/3} \cdot H) \\
&= -1.627 + 0.97083 \,\mathrm{Ln}\,(21.7 \times 14.8 \times 75.0) \\
&= -1.627 + 0.97083 \,\mathrm{Ln}\,(24087.00) \\
&= -1.627 + 0.97083\,(10.089) \\
&= -1.627 + 9.795 \\
\mathrm{Ln}(W) &= 8.168
\end{aligned}
$$

$W = e^{8.168}$; total bole green weight $= 3526$ lb.

To calculate bole dry weight (W) using $X = [(D \cdot D_{1/2} + D^2_{1/4})H]$ and the parameter estimates from table 6:

$$
\begin{aligned}
\mathrm{Ln}(W) &= b_0 + b_1 \,\mathrm{Ln}\,[(D \cdot D_{1/2} + D^2_{1/4})H] \\
&= -2.938 + 0.99936 \,\mathrm{Ln}\,[(21.7 \times 11.5 + 15.5 \times 15.5) \times 75.0] \\
&= -2.938 + 0.99936 \,\mathrm{Ln}\,[(249.55 + 240.25) \times 75.0] \\
&= -2.938 + 0.99936 \,\mathrm{Ln}\,[489.80 \times 75.0] \\
&= -2.938 + 0.99936 \,\mathrm{Ln}\,[36735.00] \\
&= -2.938 + 0.99936\,(10.511) \\
&= -2.938 + 10.504 \\
\mathrm{Ln}(W) &= 7.566
\end{aligned}
$$

$W = e^{7.566}$; total bole dry weight $= 1931$ lb.

Merchantable bole estimates to, say, an 8-inch top are calculated using equation 3 to estimate the merchantable portion of the bole and then multiplying that proportion (R8) by the predicted bole estimate of interest. Letting $DI = 8.0$, $X = [(21.7 - 8.0)/21.7]$, or $X = 0.631$, and from (3):

$$
\begin{aligned}
R8 &= [1.0 + \mathrm{EXP}\,(1.58529 + 1.83111\,(0.631) - 51.10565\,(0.631)^2 + 91.90861\,(0.631)^3 - 54.30496\,(0.631)^4)]^{-1} \\
&= [1.0 + \mathrm{EXP}\,(1.58529 + 1.83111\,(0.631) - 51.10565\,(0.39816) + 91.90861\,(0.25124) - 54.30496\,(0.15853))]^{-1} \\
&= [1.0 + \mathrm{EXP}\,(1.58529 + 1.15543 - 20.34823 + 23.09112 - 8.60897)]^{-1} \\
&= [1.0 + \mathrm{EXP}\,(-3.12536)]^{-1} \\
&= [1.0 + 0.04392]^{-1} \\
&= [1.04392]^{-1} \\
R8 &= 0.958.
\end{aligned}
$$

Then bole wood volume to an 8-inch top (V8) can be calculated:

$$
\begin{aligned}
V8 &= (R8)(\text{predicted total bole wood volume}) \\
&= (0.958)(61.6) \\
&= 59.0 \text{ ft}^3.
\end{aligned}
$$

Of course, total bole volumes or weights can be calculated using any one of the three sets of parameter estimates given in tables 1, 5, or 6. Then any of these total bole calculations can be used with the estimate of merchantable proportion to calculate merchantable bole values. The choice of which set of equations to use is left to the user, who must balance inventory precision against inventory cost.

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Schlaegel, Bryce E. Sugarberry volume and weight tables. Res. Pap. SO-205. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1984. 13 p.

A sample of 121 trees from the Mississippi Delta is used to construct volume and weight tables for sugarberry.

Additional keywords: *Celtis laevigata*, merchantable bole estimates, biomass.

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Green Ash Volume and Weight Tables

Bryce E. Schlaegel

SUMMARY

Volume and weight tables were constructed from a 70-tree sample of green ash *(Fraxinus pennsylvanica* Marsh.) taken in the Mississippi Delta. The tables present cubic-foot volume, green weight, and dry weight of bole wood, bole wood plus bark, and total tree excluding leaves above a 1-foot stump as predicted from the allometric model $\mathrm{Ln}\, Y = b_0 + b_1 \mathrm{Ln}(D^2H)$. Merchantable bole volume and weight estimates can be made to any outside bark diameter limit. More precise bole estimates can be obtained from equations using upper bole diameters taken at relative heights of 25, 33, and 50 percent of total tree height.

Green Ash Volume and Weight Tables

Bryce E. Schlaegel

INTRODUCTION

Green ash *(Fraxinus pennsylvanica* Marsh.) is distributed over most of the United States and southern Canada east of the Rocky Mountains (Little 1979) (fig. 1). It is most commonly found on alluvial soils along rivers and streams. On good sites it can develope a large, clear bole, reach a height of 110 feet, and have a dbh in excess of 30 inches. Commonly the trees reach heights of 60 to 80 feet with dbh ranging from 22 to 26 inches.

In recent years there has been considerable demand for volume and weight tables for bottomland hardwood species. This paper is the sixth in a series of six giving both volume and weight tables for some of the major bottomland hardwood species. The other five species in the series are willow oak *(Quercus phellos* L.) (Schlaegel 1981), Nuttall oak *(Q. nuttallii* Palmer) (Schlaegel and Willson 1983), overcup oak *(Q. lyrata* Walt.) (Schlaegel 1984a), sugarberry *(Celtis laevigata* Willd.) (Schlaegel 1984b), and sweetgum *(Liquidambar styraciflua* L.) (Schlaegel 1984c).

METHODS

The data were collected from 12 natural bottomland hardwood stands in west-central Mississippi. Stands were either even- or uneven-aged with a mixed species composition. Each stand was measured for species composition and diameter distribution; 70 trees, ranging in dbh from 1 through 31 inches, were chosen for destructive sampling. The sample consisted of growing stock trees from both the overstory and understory with healthy crowns and no visible signs of disease or decay. When available, three trees were selected from each 1-inch diameter class. Cutting was done throughout the year.

Stump height and total height were measured on each felled sample tree. Disks about 1-inch thick were cut from the bole at regular intervals from the stump to the top of the tree. These were then sealed in separate polyethylene bags for laboratory determination of moisture content and specific gravity. The first disk was at stump height and the remainder at 5-foot intervals measured from ground level for trees 5 intervals measured from ground level for trees 5 inches dbh and larger and at 3-foot intervals for trees smaller than 5 inches dbh. All limbs, including leaves, were weighed on 65 of the trees.

In the laboratory, both wood and bark moisture content and specific gravity were determined as follows:

1. Wood and bark were separated with a hammer and chisel.
2. Each component was weighed green.
3. Both wood and bark were soaked in water for at least an hour to ensure complete swelling.
4. Volumes were obtained by immersion (Heinrichs and Lassen 1970).
5. Wood and bark were dried in a forced-air oven at 105°C for at least 48 hours.
6. Wood or bark moisture content =
   $$\frac{\text{green weight} - \text{ovendry weight}}{\text{ovendry weight}}.$$
7. Specific gravity =
   $$\frac{\text{ovendry wood or bark weight (g)}}{\text{green wood or bark volume (cm}^3\text{)}}.$$

Average tree moisture content and specific gravity were calculated from weighted averages of the disk moisture contents and specific gravities; each disk specific gravity or moisture content was weighted by its squared average diameter.

Taper functions (Schlaegel 1981, Schlaegel and Willson 1983) of the form

$$Y = b_1(X^1 - 1) + b_2(X^2 - 1) + \dots + b_p(X^p - 1)$$

where

Y = d/D,
d = diameter at height h on the bole,
D = dbh,
X = h/H,
h = height from ground to a specific measurement point,
H = total height,
b_i = coefficients estimated for each tree by linear regression; $i = 1, 2, \dots p$; $4 \leq p \leq 7$,

were calculated for each tree, both inside and outside bark. Cubic-foot volumes were obtained for each tree by integrating the taper function to heights of specific top diameters to obtain both total and merchant-

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able bole volumes. Bole green and dry weights were calculated from estimated tree volume and weighted average tree density and moisture content.

Allometric regression equations were used to estimate volume, green weight, and dry weight of bole wood, bole wood plus bark, and bole wood plus bark plus limbs.

RESULTS

Characteristics of the trees used in this study are:

	Average	Range
Age *(years)*	50	14 – 168
Dbh *(in)*	8.0	0.9 – 30.6
Total height *(ft)*	51	14 – 110
Wood moisture content *(percent)*	57	40 – 141
Bark moisture content *(percent)*	115	45 – 236
Wood specific gravity	0.563	0.416 – 0.694
Bark specific gravity	0.456	0.259 – 0.610
Wood + bark green density *(lb/ft)*	55.95	43.46 – 72.00
Wood + bark dry density *(lb/ft)*)	33.84	26.23 – 40.55
Wood + bark moisture content *(percent)*	66	46 – 177
Wood + bark specific gravity	0.542	0.420 – 0.649

Individual tree volumes and weights were fitted to the allometric model:

$$\mathrm{Ln}(Y) = b_0 + b_1\,\mathrm{Ln}(D^2H) \qquad (1)$$

where

Y = the volume or weight variable of interest,

Ln is a natural logarithm;

b_0 and b_1 are coefficients estimated from the data.

Estimates of the coefficients b_0 and b_1 are presented in table 1 for predicting cubic foot volume and green and dry weight of bole wood, bole bark, total bole, and total tree excluding leaves. Additional statistics presented are the component average, fit index, regression standard error of estimate ($\hat{S}_e$) based on residuals after converting to actual units, and coefficient of variation (C.V.) of predictions in arithmetic units. Fit index, which is similar to R^2, is used to judge equation efficiency when the dependent variable has been transformed (Farrar 1978) and is calculated in untransformed units from the total and residual sums of squares.[1] The fit index and R^2 are equal when a simple linear regression analysis is performed on an untransformed dependent variable.

Fit indices range from 0.887 for dry total tree weight to 0.975 for bole wood volume. A fit index of 1.0 indicates that predictions can be made without

---

[1] $FI = \{1 - [\Sigma(Y_i - \hat{Y}_i)^2]/[\Sigma(Y_i - \bar{Y})^2]\}$

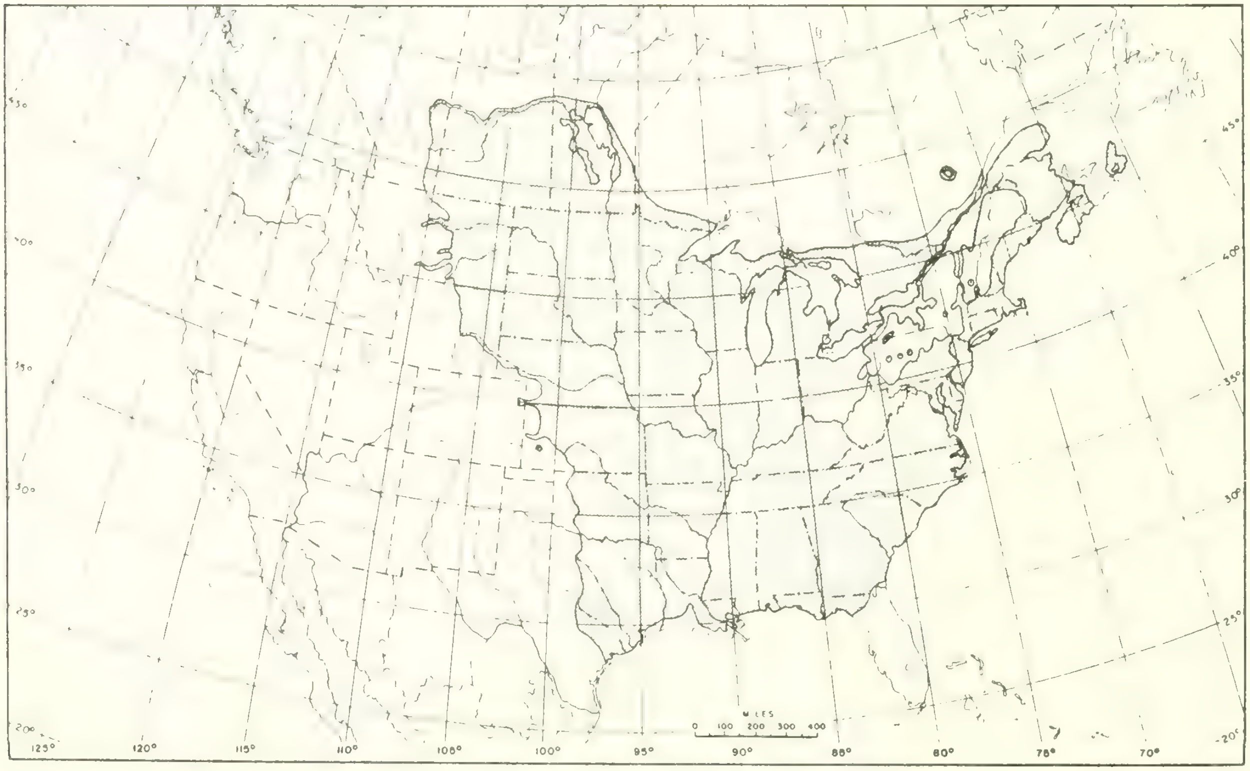

Figure 1.—*The range of green ash (Fowells 1965). (F-506594)*

error with the data used to fit the model; a value close to 1 is desirable. Coefficients of variation, which are indices of relative precision of prediction, range from 62.6 percent for dry total tree weight to 29.3 percent for bole wood volume.

Using measures of individual tree dbh and total height, estimates can be made using table 1 for tree volume (given in table 2), green weight (given in table 3), and dry weight (given in table 4) for bole wood, bole wood plus bark, and for bole wood plus bark plus limbs excluding leaves.

The equations were developed using trees from a limited geographic range compared to the total range. Therefore, predictions may be less precise when the equations are applied in other parts of the range. Using an upper bole diameter measurement in addition to dbh as described later should alleviate this problem.

MERCHANTABLE BOLE ESTIMATES

The merchantable bole is defined as the tree bole from a 1-foot stump to a specified top diameter, ignoring limbs. Merchantable bole volume or weight can be expressed as a proportion of the total bole by a generalized form of the logistic model

$$R_I = (1.0 + e^{f(X)})^{-1} \tag{2}$$

where

R_I = ratio of merchantable bole volume or weight to total bole volume or weight, where I = top outside bark diameter of merchantable bole,

$X = (D - d_I)/D$,

D = tree dbh outside bark, and

d_I = outside bark top diameter.

For a specific top diameter, the ratio of merchantable bole to total bole is the same for volume, green weight, dry weight, and inside and outside bark (Schlaegel and Willson 1983).

Model 2 was fitted to the overcup oak data for trees ≥ 4.6 inches dbh, with $f(X) = b_0 + b_1X + b_2X^2 + b_3X^3 + b_4X^4$. Inverting (2) and taking the natural logarithm results in

$$\mathrm{Ln}\left(\frac{1 - R_I}{R_I}\right) = b_0 + b_1X + b_2X^2 + b_3X^3 + b_4X^4;$$

this was solved using multiple linear regression techniques giving:

$$R_I = [1.0 + \mathrm{EXP}\,(0.77188 + 11.26543\,X - 73.62613\,X^2 + 111.38621\,X^3 - 59.39594\,X^4)]^{-1} \tag{3}$$

with fit index = 0.921 and $\hat{S}_e = 0.065$; EXP is the base of the natural logarithm and equals 2.71828.

Volume or weight to any top diameter (V_I) is found by multiplying the ratio estimate obtained from (3) by a total bole volume or weight estimate from either table 2, 3, or 4:

$$V_I = R_I \cdot V_T,$$

where V_T is the total bole volume or weight of interest.

IMPROVED TOTAL BOLE ESTIMATES

The precision of the merchantable bole estimate depends upon accuracy in measuring total bole. Total bole estimates can be significantly improved by measuring one or two additional diameters. Tables 5 and 6 give regression statistics for total bole volume and weight under two different model forms:

$$\mathrm{Ln}(Y) = b_0 + b_1\,\mathrm{Ln}(D \cdot D_{1/3} \cdot H) \tag{4}$$

and

$$\mathrm{Ln}(Y) = b_0 + b_1\,\mathrm{Ln}[(D \cdot D_{1/2} + D^2_{1/4}) \cdot H] \tag{5}$$

where D, H, and Y are as defined previously, and $D_{1/3}$, $D_{1/2}$, and $D_{1/4}$ are diameters measured outside the bark at one-third, one-half, and one-fourth the total height.

Statistics from tables 5 and 6 show the significant ($\alpha = 0.05$) improvement over the previous D^2H equations of table 1. Measuring one additional diameter at one-third the tree height reduces $\hat{S}_e$ for all bole components from 31 percent for dry bole bark to 63 percent for bole wood volume.

Measuring two upper bole diameters at one-fourth and one-half total height will result in further significant increases in precision. Improvements over the D^2H model range from 46 to 81 percent for bole wood and total bole and from 38 to 49 percent for bark.

Taking additional bole measures means a higher inventory cost, since more time will be spent at each tree, but most of the inventory cost is in traveling to the candidate tree. Data presented in this paper allow total and merchantable bole estimates to be made with high reliability. Each user has to decide when increased precision is needed and whether the need offsets the higher cost.

LOCAL VOLUME TABLES

There are many occasions when the only tree variable available is dbh, or perhaps only a rough estimate of tree volume or weight is needed. In these cases a local volume table will suffice. Table 7 gives the statistics needed for estimating by the local volume table technique. However, it must be realized that estimation precision may be considerably lessened. The local volume or weight model is

$$\mathrm{Ln}(Y) = b_0 + b_1\,\mathrm{Ln}(D^2). \tag{6}$$

Precision is significantly ($\alpha = 0.05$) reduced when only dbh is used for prediction, except for total tree and dry bole wood.

CALCULATING CONFIDENCE LIMITS

Confidence limits ($(1 - \alpha)$ percent confidence limits) of individual predictions can be calculated using statistics presented in table 8. Clark et al. (1980) used the technique of Land (1972) to estimate approximate confidence limits for lognormal means of scarlet oak:

$$Y_{U.L.} = EXP\left\{ Ln(Y) \pm Z_{\alpha/2}\left[S^2_{y \cdot x}\left[\frac{1}{n} + \frac{(X-\overline{X})^2}{\Sigma(X-\overline{X})^2}\right] + \frac{S^4_{y \cdot x}}{2(n+1)}\right]^{1/2}\right\}$$

where:

$Y_{U.L.}$ = upper and lower limits for Y,

EXP = base of natural logarithm; EXP = e = 2.71828,

Y = predicted volume or weight of component,

$Z_{\alpha/2}$ = value for the upper $\alpha/2$ percentage point from the standard normal table,

$S_{y \cdot x}$ = standard error of estimate for prediction equation,

n = number of observations used to develop the equation,

$\overline{X}$ = sample mean of Ln(X),

$\Sigma(X-\overline{X})^2$ = corrected sum of squares for Ln(X),

X = $Ln(D^2H)$; D = dbh and H = total height of tree for which Y is predicted.

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Table 1.—*Regression statistics for predicting green ash tree volumes and weights using dbh and total height*[1]

Component	Average Y	b_0	b_1	Fit index[2]	$\hat{S}_e$[3]	C.V. percent[4]
			Volume *(cubic feet)*			
Bole wood	14.4	−5.817	0.93265	0.975	4.22	29.3
Bole bark	2.5	−6.743	0.85307	0.939	0.99	40.4
Total bole	16.9	−5.502	0.91740	0.973	4.99	29.6
Total tree, excluding leaves	22.7	−5.371	0.92436	0.947	9.60	42.3
			Green weight *(pounds)*			
Bole wood	717	−1.616	0.90470	0.939	322	44.9
Bole bark	127	−2.335	0.80534	0.953	45	35.3
Total bole	844	−1.246	0.88369	0.945	355	42.0
Total tree, excluding leaves	1138	−1.104	0.88814	0.908	632	55.5
			Dry weight *(pounds)*			
Bole wood	469	−2.123	0.91416	0.907	263	56.1
Bole bark	77	−3.536	0.87524	0.941	32	41.1
Total bole	546	−1.905	0.90737	0.917	285	52.3
Total tree, excluding leaves	733	−1.759	0.91023	0.887	459	62.6

[1] Volumes and weights of trees from a 1-foot stump to the tree tip, using $\mathrm{Ln}(Y) = b_0 + b_1 \mathrm{Ln}(D^2H)$; D = dbh, H = total tree height.

[2] Fit index = $1.0 - [\Sigma(Y-\hat{Y})^2 / \Sigma(Y-\overline{Y})^2]$, using untransformed values.

[3] $\hat{S}_e = [\Sigma(Y-\hat{Y})^2 / (n-2)]^{1/2}$, using untransformed values.

[4] Coefficient of variation = $100\ \hat{S}_e / \overline{Y}$.

Table 2.—*Cubic-foot volume for green ash bole wood, bole wood plus bark, and total tree*[1]

	Total height in feet												
Dbh	10	20	30	40	50	60	70	80	90	100	110	120	130
inches	*cubic feet*												
1	**0.03**[2]	**0.05**	**0.07**	0.09									
	0.03[3]	**0.06**	**0.09**	0.12									
	0.04	**0.07**	**0.11**	0.14									
2	0.09	**0.18**	**0.26**	**0.34**	0.42								
	0.12	**0.23**	**0.33**	**0.43**	0.53								
	0.14	**0.27**	**0.39**	**0.51**	0.62								
3		**0.38**	**0.55**	**0.72**	0.89								
		0.48	**0.69**	**0.90**	1.11								
		0.57	**0.82**	**1.07**	1.32								
4		0.65	0.94	**1.23**	1.52	1.80							
		0.81	1.18	**1.53**	1.88	2.22							
		0.96	1.40	**1.83**	2.24	2.66							
5			1.43	**1.87**	**2.30**	**2.73**	3.15						
			1.77	**2.31**	**2.83**	**3.34**	3.85						
			2.11	**2.76**	**3.39**	**4.01**	4.63						
6			2.01	2.63	**3.23**	**3.83**	4.43						
			2.47	3.22	**3.95**	**4.67**	5.38						
			2.96	3.86	**4.75**	**5.62**	6.48						
7				3.50	4.31	**5.11**	5.90	6.68					
				4.27	5.24	**6.20**	7.14	8.07					
				5.14	6.31	**7.47**	8.62	9.75					
8				4.49	5.53	**6.56**	**7.57**	8.57					
				5.46	6.70	**7.92**	**9.12**	10.30					
				6.57	8.08	**9.56**	**11.0**	12.50					
9				5.60	6.89	**8.17**	**9.43**	10.7					
				6.78	8.32	**9.83**	**11.30**	12.8					
				8.17	10.00	**11.90**	**13.71**	15.5					
10					8.39	9.94	**11.5**	13.0	14.5				
					10.10	11.90	**13.7**	15.5	17.3				
					12.20	14.40	**16.7**	18.8	21.0				
11					10.0	11.9	**13.7**	15.5	17.3				
					12.0	14.2	**16.4**	18.5	20.6				
					14.6	17.2	**19.9**	22.5	25.1				
12					11.8	14.0	**16.1**	18.3	**20.4**	22.5			
					14.1	16.7	**19.2**	21.7	**24.2**	26.6			
					17.1	20.2	**23.3**	26.4	**29.4**	32.4			
13					13.7	**16.2**	**18.7**	**21.2**	23.7	26.1			
					16.3	**19.3**	**22.2**	**25.1**	28.0	30.8			
					19.8	**23.5**	**27.1**	**30.6**	34.1	37.6			
14						18.6	21.5	**24.3**	27.2	30.0			
						22.1	25.5	**28.8**	32.1	35.3			
						26.9	31.0	**35.1**	39.1	43.1			
15						21.2	**24.4**	**27.7**	30.9	34.1			
						25.1	**28.9**	**32.7**	36.4	40.1			
						30.6	**35.2**	**39.9**	44.5	49.0			
16						23.9	**27.6**	**31.2**	34.9	38.5			
						28.3	**32.6**	**36.8**	41.0	45.1			
						34.4	**39.7**	**44.9**	50.1	55.2			
17						26.7	30.9	35.0	39.0	43.1			
						31.6	36.4	41.1	45.8	50.5			
						38.5	44.4	50.3	56.0	61.8			
18						29.8	**34.4**	38.9	43.4	47.9			
						35.1	**40.4**	45.7	50.9	56.0			
						42.8	**49.4**	55.9	62.3	68.7			

Table 2.—*Cubic-foot volume for green ash bole wood, bole wood plus bark, and total tree—(Continued)*

	Total height in feet												
Dbh	10	20	30	40	50	60	70	80	90	100	110	120	130
inches	*cubic feet*												
19						32.9	38.0	43.0	48.0	53.0			
						38.7	44.6	50.4	56.2	61.9			
						47.3	54.6	61.7	68.8	75.9			
20						36.2	41.8	47.4	52.9	58.3	63.7		
						42.5	49.0	55.4	61.7	68.0	74.2		
						52.0	60.0	67.9	75.7	83.4	91.1		
21						39.7	45.8	51.9	57.9	63.9	69.8		
						46.5	53.6	60.6	67.5	74.4	81.1		
						56.9	65.7	74.3	82.8	91.3	99.7		
22						43.3	49.9	56.6	63.1	69.7	76.1	82.6	
						50.7	58.4	66.0	73.5	81.0	88.4	95.7	
						62.1	71.6	81.0	90.3	99.5	109.0	118.0	
23						47.0	54.3	61.5	68.6	**75.7**	82.7	89.7	
						55.0	63.3	71.6	79.8	**87.9**	95.9	104.0	
						67.4	77.7	87.9	98.0	**108.0**	118.0	128.0	
24						50.9	58.8	66.5	74.3	81.9	89.6	97.1	105
						59.5	68.5	77.4	86.3	95.0	104.0	112.0	121
						72.9	84.0	95.1	106.0	117.0	128.0	138.0	149
25						54.9	63.4	71.8	80.1	88.4	96.6	105	113
						64.1	73.8	83.4	93.0	102.0	112.0	121	130
						78.6	90.6	103.0	114.0	126.0	138.0	149	161
26						59.1	68.2	77.3	86.2	95.1	104	113	121
						68.9	79.3	89.7	99.9	110.0	120	130	140
						84.5	97.5	110.0	123.0	136.0	148	160	173
27						63.4	73.2	**82.9**	92.5	**102**	112	121	130
						73.8	85.0	**96.1**	107.0	**118**	129	139	150
						90.6	104.0	**118.0**	132.0	**145**	159	172	185
28							78.3	88.7	99	109	119	129	139
							90.9	103.0	114	126	138	149	160
							112.0	126.0	141	155	170	184	198
29							83.6	94.7	**106**	117	127	138	149
							96.9	110.0	**122**	134	147	159	171
							119.0	135.0	**150**	166	181	196	211
30							89.1	101	113	124	136	147	159
							103.0	117	130	143	156	169	182
							127.0	144	160	177	193	209	225
31							94.7	107	120	132	**144**	157	169
							110.0	124	138	152	**166**	180	193
							135.0	153	170	188	**205**	222	239
32							100	114	127	140	153	166	179
							116	131	146	161	176	190	205
							143	162	180	199	217	235	253
33							106	121	135	148	162	176	190
							123	139	155	170	186	201	217
							151	171	191	211	230	249	268
34							113	127	142	157	172	186	200
							130	147	163	180	196	213	229
							160	181	202	223	243	263	284
35							119	135	150	166	181	196	212
							137	155	172	190	207	224	241
							169	191	213	235	256	278	299

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[1] Tree volume from a 1-foot stump to the tree tip.

[2] The three vertical figures for each dbh give volumes of bole wood first, bole wood plus bark second, and total tree (bole wood plus bark plus limbs excluding leaves) last.

[3] Boldface numbers span the range of the data.

Table 3.—*Green weight in pounds for green ash bole wood, bole wood plus bark, and total tree*[1]

Dbh	Total height in feet												
	10	20	30	40	50	60	70	80	90	100	110	120	130
inches	*pounds*												
1	1.6[2]	3.0	4.3	5.6									
	2.2[3]	4.1	5.8	7.5									
	2.6	4.7	6.8	8.8									
2	5.6	10.5	15	20	24								
	7.5	13.8	20	26	31								
	8.8	16.0	23	30	37								
3		22	31	41	50								
		28	40	52	64								
		33	48	62	75								
4		37	53	69	84	99							
		47	67	87	106	124							
		56	80	103	126	148							
5			79	103	126	148	171						
			100	129	157	184	211						
			119	153	187	219	252						
6			110	143	175	206	237						
			138	178	217	254	292						
			164	212	258	303	348						
7				189	231	273	314	354					
				233	284	334	383	431					
				278	339	399	457	515					
8				241	295	347	399	451					
				296	360	423	485	545					
				353	430	506	580	653					
9				298	365	430	494	558					
				364	443	521	597	672					
				435	530	623	715	805					
10					441	520	598	675	751				
					534	627	719	809	898				
					639	752	862	971	1078				
11					524	618	711	802	892				
					632	743	851	958	1063				
					757	890	1021	1150	1276				
12					614	724	832	939	1044	1149			
					737	866	992	1117	1239	1360			
					884	1039	1192	1342	1490	1636			
13					709	836	962	1085	1207	1328			
					849	998	1143	1286	1427	1567			
					1019	1198	1374	1547	1717	1886			
14						956	1100	1241	1380	1518			
						1137	1303	1466	1627	1786			
						1367	1567	1764	1959	2151			
15						1084	1246	1406	1564	1720			
						1285	1472	1657	1838	2018			
						1545	1771	1994	2214	2432			
16						1218	1400	1580	1758	1933			
						1440	1650	1857	2060	2261			
						1732	1987	2237	2483	2727			
17						1359	1562	1763	1961	2158			
						1603	1837	2067	2293	2517			
						1929	2212	2491	2766	3037			
18						1507	1733	1955	2175	2393			
						1773	2032	2286	2537	2785			
						2136	2449	2757	3061	3362			

Table 3.—*Green weight in pounds for green ash bole wood, bole wood plus bark, and total tree—(Continued)*

	Total height in feet												
Dbh	10	20	30	40	50	60	70	80	90	100	110	120	130
inches	pounds												
19						1662	1911	2156	2399	2638			
						1951	2236	2516	2792	3064			
						2351	2696	3035	3370	3700			
20						1824	2097	2366	2632	2895	3156		
						2136	2448	2754	3057	3355	3650		
						2575	2953	3325	3691	4053	4411		
21						1992	2290	2584	2875	3162	3447		
						2328	2668	3002	3332	3657	3978		
						2808	3220	3626	4025	4420	4811		
22						2167	2491	2811	3127	3440	3750	4057	
						2528	2897	3260	3617	3970	4319	4664	
						3050	3498	3938	4372	4801	5225	5645	
23						2348	2700	3047	3389	**3728**	4064	4397	
						2735	3134	3526	3913	**4295**	4672	5046	
						3301	3785	4261	4731	**5196**	5654	6109	
24						2536	2916	3290	3660	4027	4389	4749	5105
						2948	3378	3802	4219	4630	5037	5440	5838
						3560	4082	4596	5103	5604	6098	6588	7074
25						2731	3140	3543	3941	4335	4726	5113	5497
						3169	3631	4086	4534	4977	5414	5847	6275
						3828	4389	4942	5487	6025	6557	7084	7606
26						2932	3370	3803	4231	4654	5073	5489	5901
						3396	3892	4379	4860	5334	5803	6266	6726
						4104	4706	5298	5883	6460	7030	7595	8155
27						3139	3609	**4072**	4530	**4983**	5432	5877	6318
						3631	4160	**4681**	5195	**5702**	6203	6699	7190
						4388	5032	**5666**	6290	**6908**	7518	8122	8720
28							3854	4349	4838	5322	5801	6276	6748
							4437	4992	5540	6080	6615	7143	7667
							5368	6044	6710	7368	8019	8664	9302
29							4107	4634	5155	**5671**	6181	6688	7190
							4720	5312	5894	**6469**	7038	7600	8157
							5713	6432	7142	**7842**	8535	9221	9900
30							4367	4927	5481	6030	6573	7111	7645
							5012	5640	6258	6869	7472	8070	8661
							6068	6832	7585	8329	9065	9793	10515
31							4634	5228	5816	6398	**6974**	7545	8112
							5311	5976	6632	7279	**7918**	8551	9178
							6432	7241	8040	8829	**9609**	10381	11145
32							4907	5538	6160	6776	7387	7992	8592
							5617	6321	7014	7699	8375	9045	9708
							6805	7662	8506	9341	10166	10983	11792
33							5188	5855	6513	7164	7810	8449	9084
							5931	6674	7406	8129	8843	9550	10250
							7187	8092	8984	9866	10737	11600	12454
34							5476	6180	6875	7562	8243	8918	9588
							6253	7036	7808	8569	9323	10068	10806
							7578	8533	9474	10403	11322	12231	13133
35							5771	6512	7245	7969	8687	9398	10104
							6581	7406	8218	9020	9813	10597	11374
							7979	8984	9974	10953	11920	12878	13827

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[1] Tree weight from a 1-foot stump to the tree tip.

[2] The three vertical figures for each dbh give weights of bole wood first, bole wood plus bark second, and total tree (bole wood plus bark plus limbs excluding leaves) last.

[3] Boldface numbers span the range of the data.

Table 4.—*Dry weight in pounds for green ash bole wood, bole wood plus bark, and total tree*[1]

	Total height in feet												
Dbh	10	20	30	40	50	60	70	80	90	100	110	120	130
inches	*pounds*												
1	1.0[2]	1.8	2.7	3.5									
	1.2[3]	2.3	3.3	4.2									
	1.4	2.6	3.8	5.0									
2	3.5	6.6	9.5	12.4	15								
	4.2	7.9	11.5	14.9	18								
	4.9	9.3	13.4	17.0	21								
3		14	20	26	32								
		17	24	31	38								
		19	28	37	45								
4		23	34	44	54	64							
		28	40	52	64	76							
		33	47	62	76	89							
5			51	66	81	96	110						
			60	78	96	113	130						
			71	93	113	134	154						
6			71	92	113	134	154						
			84	109	134	158	182						
			99	129	158	187	215						
7				122	150	177	204	231					
				145	177	209	240	271					
				171	209	247	284	321					
8				156	192	226	261	294					
				184	225	266	306	345					
				218	267	315	363	410					
9				194	238	281	323	365					
				228	279	329	379	428					
				270	331	391	449	508					
10					288	340	392	443	493				
					338	399	459	518	576				
					401	473	545	615	684				
11					343	405	466	527	587				
					402	474	545	616	685				
					477	563	648	731	814				
12					402	475	547	618	688	758			
					471	555	639	721	802	883			
					559	659	759	857	954	1050			
13					465	550	633	715	796	877			
					544	642	739	834	928	1021			
					646	763	878	991	1104	1215			
14						630	725	819	912	1004			
						735	845	954	1061	1168			
						873	1005	1135	1263	1390			
15						714	822	929	1035	1139			
						833	958	1081	1203	1323			
						990	1139	1286	1432	1576			
16						804	925	1045	1164	1282			
						936	1077	1215	1352	1488			
						1113	1281	1447	1610	1773			
17						898	1034	1168	1301	1432			
						1045	1202	1357	1510	1661			
						1243	1431	1616	1798	1979			
18						997	1147	1296	1444	1590			
						1159	1333	1505	1674	1842			
						1380	1587	1793	1996	2196			

Table 4.—*Dry weight in pounds for green ash bole wood, bole wood plus bark, and total tree—(Continued)*

	Total height in feet												
Dbh	10	20	30	40	50	60	70	80	90	100	110	120	130
inches							*pounds*						
19						1100	1267	1431	1594	1755			
						1279	1470	1660	1847	2032			
						1522	1752	1978	2702	2424			
20						1208	1391	1572	1751	1928	2103		
						1403	1614	1822	2027	2231	2432		
						1671	1923	2172	2417	2661	2902		
21						1321	1521	1719	1914	2107	2299		
						1533	1763	1990	2215	2437	2657		
						1827	2102	2373	2642	2908	3171		
22						1438	1656	1871	2084	2295	2503	2711	
						1668	1919	2166	2410	2652	2891	3129	
						1988	2288	2583	2875	3165	3452	3736	
23						1560	1796	2030	2260	**2489**	2715	2940	
						1808	2080	2348	2613	**2875**	3134	3392	
						2156	2480	2801	3118	**3432**	3743	4051	
24						1686	1942	2194	2443	2690	2935	3178	3419
						1954	2247	2536	2822	3106	3386	3664	3940
						2329	2680	3027	3369	3708	4044	4378	4708
25						1817	2092	2364	2632	2899	3163	3424	3684
						2104	2420	2731	3039	3344	3646	3946	4243
						2509	2887	3260	3629	3994	4356	4715	5072
26						1952	2248	2539	2828	3114	3398	3679	3958
						2259	2598	2933	3264	3591	3915	4237	4556
						2695	3101	3501	3898	4290	4679	5064	5447
27						2092	2408	**2721**	3030	**3337**	3640	3942	4241
						2419	2782	**3141**	3495	**3846**	4193	4537	4879
						2886	3321	**3750**	4175	**4595**	5011	5424	5834
28							2574	2908	3239	3566	3891	4213	4533
							2972	3355	3733	4108	4479	4847	5212
							3548	4007	4460	4909	5354	5796	6234
29							2744	3101	3453	**3802**	4148	4492	4833
							3168	3576	3979	**4378**	4774	5166	5555
							3782	4271	4755	**5233**	5708	6178	6645
30							2920	3299	3674	4045	4414	4779	5142
							3369	3802	4231	4656	5076	5493	5907
							4023	4543	5057	5566	6071	6571	7068
31							3100	3503	3901	4295	**4686**	5074	5460
							3575	4036	4491	4941	**5388**	5830	6269
							4271	4823	5368	5909	**6444**	6975	7503
32							3286	3712	4134	4552	4966	5378	5786
							3787	4275	4757	5234	5707	6176	6641
							4525	5110	5688	6260	6828	7391	7949
33							3476	3927	4373	4816	5254	5689	6121
							4005	4520	5030	5535	6035	6531	7023
							4786	5404	6016	6621	7221	7816	8407
34							3671	4147	4619	5086	5549	6008	6464
							4228	4772	5310	5843	6371	6894	7414
							5053	5706	6352	6991	7624	8253	8877
35							3870	4373	4870	5362	5851	6335	6816
							4456	5030	5597	6159	6715	7267	7814
							5327	6015	6696	7370	8038	8700	9358

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[1] Tree weight from a 1-foot stump to the tree tip.

[2] The three vertical figures for each dbh give weights of bole wood first, bole wood plus bark second, and total tree (bole wood plus bark plus limbs excluding leaves) last.

[3] Boldface numbers span the range of the data.

Table 5.—*Regression statistics for predicting green ash bole volumes and weights using two bole diameter measurements and total height*[1]

Component	Average Y	b_0	b_1	Fit index[2]	$\hat{S}_e$[3]	C.V. percent[4]
			Volume *(cubic feet)*			
Bole wood	14.4	−5.868	0.97894	0.997	1.57*	10.9
Bole bark	2.5	−6.804	0.89660	0.975	0.63*	25.8
Total bole	16.9	−5.556	0.96315	0.996	1.86*	11.0
			Green weight *(pounds)*			
Bole wood	717	−1.671	0.94999	0.978	193*	26.9
Bole bark	127	−2.394	0.84651	0.982	28*	21.7
Total bole	844	−1.301	0.92811	0.981	208*	24.6
			Dry weight *(pounds)*			
Bole wood	469	−2.183	0.96029	0.960	171*	36.6
Bole bark	77	−3.605	0.92033	0.971	22*	29.0
Total bole	546	−1.967	0.95330	0.967	180*	33.0

[1] Volumes and weights of trees from a 1-foot stump to the tree tip, using $\mathrm{Ln}(Y) = b_0 + b_1 \mathrm{Ln}(D \cdot D_{1/3} \cdot H)$; D = dbh, H = total tree height, $D_{1/3}$ = bole diameter outside bark at ⅓H.

[2] Fit index = $1.0 - [\Sigma(Y - \hat{Y})^2 / \Sigma(Y - \overline{Y})^2]$, using untransformed values.

[3] $\hat{S}_e = [\Sigma(Y - \hat{Y})^2 / (n - 2)]^{1/2}$, using untransformed values.

[4] Coefficient of variation = $100\ \hat{S}_e / \overline{Y}$.

*Significantly more precise by the F test than D^2H model; $\alpha = 0.05$.

Table 6.—*Regression statistics for predicting green ash bole volumes and weights using three bole diameter measurements and total height*[1]

Component	Average Y	b_0	b_1	Fit index[2]	$\hat{S}_e$[3]	C.V. percent[4]
			Volume *(cubic feet)*			
Bole wood	14.4	−6.609	1.00941	0.999	0.90+	6.2
Bole bark	2.5	−7.490	0.92503	0.981	0.56*	22.8
Total bole	16.9	−6.286	0.99323	0.999	0.97+	5.7
			Green weight *(pounds)*			
Bole wood	717	−2.392	0.97969	0.987	151+	21.0
Bole bark	127	−3.042	0.87346	0.988	23*	17.9
Total bole	844	−2.007	0.95724	0.989	159+	18.8
			Dry weight *(pounds)*			
Bole wood	469	−2.914	0.99049	0.973	141*	30.1
Bole bark	77	−4.312	0.94977	0.976	20*	26.0
Total bole	546	−2.693	0.98336	0.979	144*	26.4

[1] Volumes and weights of trees from a 1-foot stump to the tree tip, using $\mathrm{Ln}(Y) = b_0 + b_1 \mathrm{Ln}[(D \cdot D_{1/2} + D^2_{1/4})H]$; D = dbh, H = total tree height, $D_{1/2}$ and $D_{1/4}$ = bole diameters outside bark at ½H and ¼H, respectively.

[2] Fit index = $1.0 - [\Sigma(Y - \hat{Y})^2 / \Sigma(Y - \overline{Y})^2]$, using untransformed values.

[3] $\hat{S}_e = [\Sigma (Y - \hat{Y})^2 / (n - 2)]^{1/2}$, using untransformed values.

[4] Coefficient of variation = $100\ \hat{S}_e / \overline{Y}$.

+Significantly more precise by the F test than $D \cdot D_{1/3} \cdot H$ model; $\alpha = 0.05$.

*Significantly more precise by the F test than D^2H model; $\alpha = 0.05$.

Table 7.—*Local volume and weight equations for green ash*[1]

Component	Average Y	b_0	b_1	Fit index[2]	$\bar{S}_e$[3]	C.V. percent[4]
			Volume *(cubic feet)*			
Bole wood	14.4	3.060	1.17920	0.940	6.48*	45.0
Bole bark	2.5	−4.222	1.07848	0.885	1.36*	55.6
Total bole	16.9	−2.791	1.15993	0.938	7.57*	44.9
Total tree, excluding leaves	22.7	−2.644	1.17048	0.928	11.14	49.2
			Green weight *(pounds)*			
Bole wood	717	1.062	1.14335	0.904	405*	56.5
Bole bark	127	0.036	1.01914	0.923	57*	44.9
Total bole	844	1.367	1.11714	0.915	441*	52.2
Total tree, excluding leaves	1138	1.518	1.12431	0.900	660	58.0
			Dry weight *(pounds)*			
Bole wood	469	0.589	1.15466	0.861	321	68.5
Bole bark	77	−0.953	1.10694	0.901	41*	53.3
Total bole	546	0.784	1.14630	0.873	352*	64.6
Total tree, excluding leaves	733	0.935	1.15150	0.871	489	66.8

[1] Volumes and weights of trees from a 1-foot stump to the tree tip, using $Ln(Y) = b_0 + b_1 Ln(D^2)$; $D = dbh$.

[2] Fit index = $1.0 - [\Sigma(Y - \hat{Y})^2 / \Sigma(Y - \bar{Y})^2]$, using untransformed values.

[3] $\hat{S}_e = [\Sigma(Y - \hat{Y})^2 / (n - 2)]^{1/2}$, using untransformed values.

[4] Coefficient of variation = $100 \hat{S}_e / \bar{Y}$.

*Significantly less precise by the F test than D^2H model; $\alpha = 0.05$.

Table 8.—*Statistics for estimating confidence bounds for green ash predictions for the bole and total tree*

Independent variable - X	n	Mean of X	Corrected sum of squares for X[1]		$S_{y \cdot x}$ Standard error of estimate for tree components		
		Bole predictions			Wood	Bark	Total
$Ln(D^2)$	70	3.155	312.623	Volume	0.2213	0.3014	0.2227
				Green weight	0.2610	0.3127	0.2509
				Dry weight	0.2977	0.3569	0.2892
$Ln(D^2H)$	70	6.930	501.821	Volume	0.1502	0.2603	0.1553
				Green weight	0.1949	0.2942	0.1941
				Dry weight	0.2257	0.3279	0.2209
$Ln(D \cdot D_{.3} \cdot H)$	70	6.647	456.642	Volume	0.0789	0.1994	0.0743
				Green weight	0.1329	0.2464	0.1267
				Dry weight	0.1594	0.2696	0.1477
$Ln[(D \cdot D_{.3} + D^2_{.4})H]$	70	7.179	429.668	Volume	0.0593	0.1773	0.0405
				Green weight	0.1162	0.2283	0.1033
				Dry weight	0.1378	0.2466	0.1202
		Total tree predictions				Total tree	
$Ln(D^2)$	65	3.001	290.532	Volume		0.2374	
				Green weight		0.2596	
				Dry weight		0.2963	
$Ln(D^2H)$	65	6.738	467.493	Volume		0.1841	
				Green weight		0.2088	
				Dry weight		0.2335	

[1] $\Sigma(X - \bar{X})^2$ in base e logarithmic units.

APPENDIX

Examples Using the Equations

In this section examples are presented to illustrate use of the equations. The following tabulation gives data used to illustrate equation use:

$D = 21.7$ in.
$H = 75.0$ ft.
$D_{1/4} = 15.5$ in.
$D_{1/3} = 14.8$ in.
$D_{1/2} = 11.5$ in.

Bole wood volume (V) is calculated using $X = D^2H$ and the parameter estimates from table 1 as follows:

$$\begin{aligned}
\mathrm{Ln}(V) &= b_0 + b_1\,\mathrm{Ln}(D^2H) \\
&= -5.817 + 0.93265\,\mathrm{Ln}\,(21.7 \times 21.7 \times 75.0) \\
&= -5.817 + 0.93265\,\mathrm{Ln}\,(35316.75) \\
&= -5.817 + 0.93265\,(10.472) \\
&= -5.817 + 9.767 \\
\mathrm{Ln}(V) &= 3.950 \\
V &= e^{3.950};\ \text{bole wood volume} = 51.9\ \text{ft}^3.
\end{aligned}$$

To calculate total green bole weight (W) using $X = D \cdot D_{1/3} \cdot H$ and the parameter estimates from table 5:

$$\begin{aligned}
\mathrm{Ln}(W) &= b_0 + b_1\,\mathrm{Ln}\,(D \cdot D_{1/3} \cdot H) \\
&= -1.301 + 0.92811\,\mathrm{Ln}\,(21.7 \times 14.8 \times 75.0) \\
&= -1.301 + 0.92811\,\mathrm{Ln}\,(24087.00) \\
&= -1.301 + 0.92811\,(10.089) \\
&= -1.301 + 9.364 \\
\mathrm{Ln}(W) &= 8.063 \\
W &= e^{8.063};\ \text{total bole green weight} = 3175\ \text{lb.}
\end{aligned}$$

To calculate bole dry weight (W) using $X = [(D \cdot D_{1/2} + D^2_{1/4})H]$ and the parameter estimates from table 6:

$$\begin{aligned}
\mathrm{Ln}(W) &= b_0 + b_1\,\mathrm{Ln}\,[(D \cdot D_{1/2} + D^2_{1/4})H] \\
&= -2.693 + 0.98336\,\mathrm{Ln}\,[(21.7 \times 11.5 + 15.5 \times 15.5) \times 75.0] \\
&= -2.693 + 0.98336\,\mathrm{Ln}\,[(249.55 + 240.25) \times 75.0] \\
&= -2.693 + 0.98336\,\mathrm{Ln}\,[489.80 \times 75.0] \\
&= -2.693 + 0.98336\,\mathrm{Ln}\,[36735.00] \\
&= -2.693 + 0.98336\,(10.511) \\
&= -2.693 + 10.336 \\
\mathrm{Ln}(W) &= 7.643 \\
W &= e^{7.643};\ \text{total bole dry weight} = 2086\ \text{lb.}
\end{aligned}$$

Merchantable bole estimates to, say, an 8-inch top are calculated using equation 3 to estimate the merchantable portion of the bole and then multiplying that proportion (R8) by the predicted bole estimate of interest. Letting $DI = 8.0$, $X = [(21.7 - 8.0)/21.7]$, or $X = 0.631$, and from (3):

$$\begin{aligned}
R8 &= [1.0 + \mathrm{EXP}\,(0.77188 + 11.26543\,(0.631) - 73.62613\,(0.631)^2 + 111.38621\,(0.631)^3 - 59.39594\,(0.631)^4)]^{-1} \\
&= [1.0 + \mathrm{EXP}\,(0.77188 + 11.26543\,(0.631) - 73.62613\,(0.39816) + 111.38621\,(0.25124) - 59.39594\,(0.15853))]^{-1} \\
&= [1.0 + \mathrm{EXP}\,(0.77188 + 7.10849 - 29.31498 + 27.98467 - 9.41604)]^{-1} \\
&= [1.0 + \mathrm{EXP}\,(-2.86598)]^{-1} \\
&= [1.0 + 0.05693]^{-1} \\
&= [1.05693]^{-1} \\
R8 &= 0.946.
\end{aligned}$$

Then bole wood volume to an 8-inch top (V8) can be calculated:

$$\begin{aligned}
V8 &= (R8)(\text{predicted total bole wood volume}) \\
&= (0.946)(51.9) \\
&= 49.1\ \text{ft}^3.
\end{aligned}$$

Of course, total bole volumes or weights can be calculated using any one of the three sets of parameter estimates given in tables 1, 5, or 6. Then any of these total bole calculations can be used with the estimate of merchantable proportion to calculate merchantable bole values. The choice of which set of equations to use is left to the user, who must balance inventory precision against inventory cost.

Schlaegel, Bryce E. Green ash volume and weight tables. Res. Pap. SO-206. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1984. 14 p.

A sample of 70 trees from the Mississippi Delta is used to construct volume and weight tables for green ash.

Additional keywords: *Fraxinus pennsylvanica*, merchantable bole estimates, biomass.

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Overcup Oak Volume and Weight Tables

Bryce E. Schlaegel

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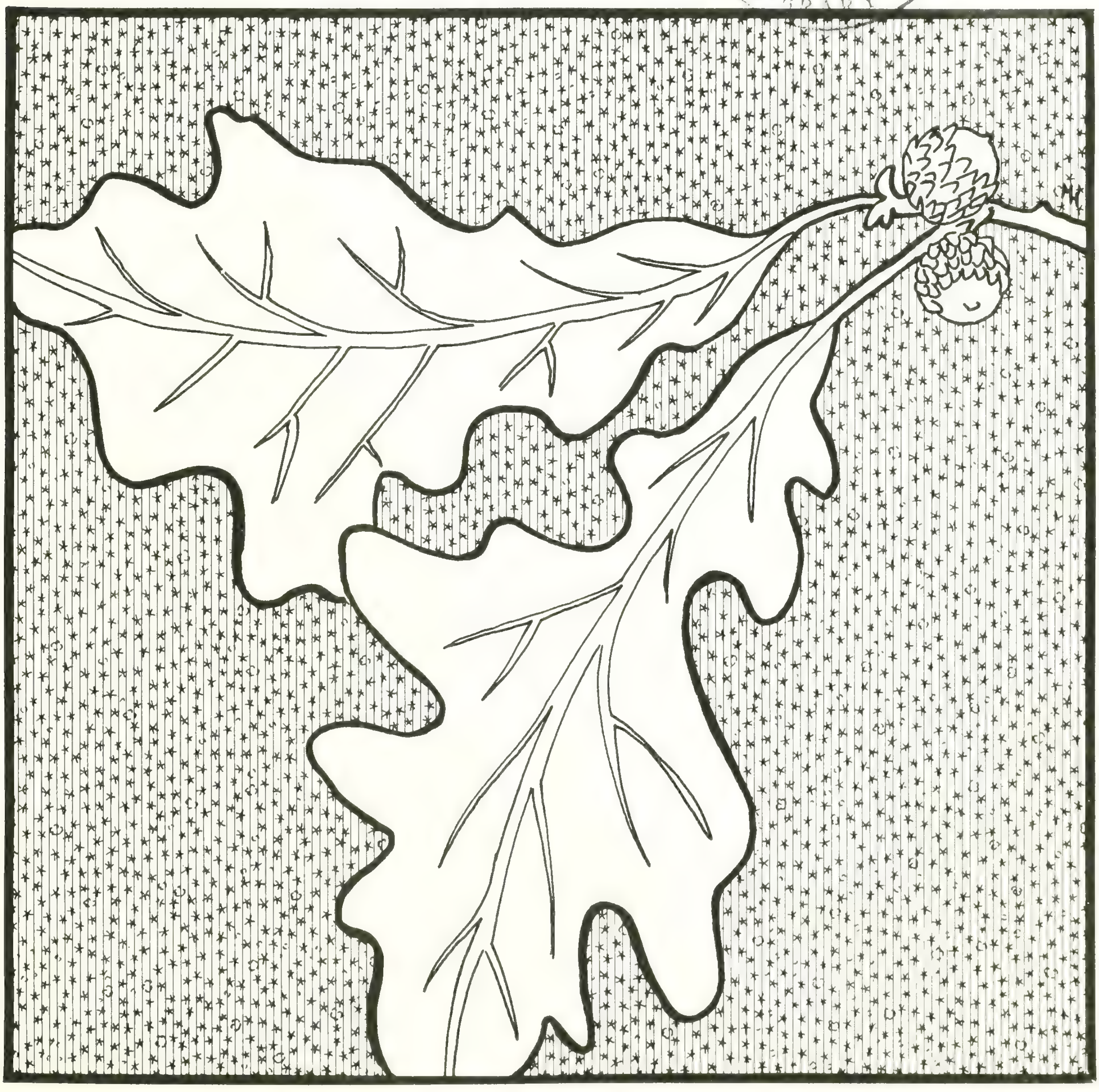

SUMMARY

Volume and weight tables were constructed from a 88-tree sample of overcup oak *(Quercus lyrata* Walt.) taken in the Mississippi Delta. The tables present cubic-foot volume, green weight, and dry weight of bole wood, bole wood plus bark, and total tree excluding leaves above a 1-foot stump as predicted from the allometric model $\text{Ln } Y = b_0 + b_1 \text{Ln}(D^2H)$. Merchantable bole volume and weight estimates can be made to any outside bark diameter limit. More precise bole estimates can be obtained from equations using upper bole diameters taken at relative heights of 25, 33, and 50 percent of total tree height.

Overcup Oak Volume and Weight Tables

Bryce E. Schlaegel

INTRODUCTION

Overcup oak *(Quercus lyrata* Walt.) grows on bottomlands of the Coastal Plain of the southern United States from Delaware and Maryland south to Georgia and northwestern Florida. Then into eastern Texas and northward along the Mississippi Valley to southern Illinois and Indiana (Little 1979) (fig. 1). It is most commonly found on the lower, poorly drained parts of first bottoms and terraces. On good sites it can develop a large, clear bole, reach a height of 100 feet, and have a dbh in excess of 34 inches. Commonly the trees are slow growing, reaching heights of 60 to 80 feet with dbh ranging from 22 to 26 inches.

In recent years there has been considerable demand for volume and weight tables for bottomland hardwood species. This paper is the third in a series of six giving both volume and weight tables for some of the major bottomland hardwood species. The other five species in the series are willow oak *(Q. phellos* L.) (Schlaegel 1981), Nuttall oak *(Q. nuttallii* Palmer) (Schlaegel and Willson 1983), sugarberry *(Celtis laevigata* Willd.) (Schlaegel 1984a), sweetgum *(Liquidambar styraciflua* L.) (Schlaegel 1984b), and green ash *(Fraxinus pennsylvanica* Marsh.) (Schlaegel 1984c).

METHODS

The data were collected from 12 natural bottomland hardwood stands in west-central Mississippi. Stands were either even- or uneven-aged with a mixed species composition. Each stand was measured for species composition and diameter distribution; 88 trees, ranging in dbh from 1 through 34 inches, were chosen for destructive sampling. The sample consisted of growing stock trees from both the overstory and understory with healthy crowns and no visible signs of disease or decay. When available, three trees were selected from each 1-inch diameter class. Cutting was done throughout the year.

Stump height and total height were measured on each felled sample tree. Disks about 1-inch thick were cut from the bole at regular intervals from the stump to the top of the tree. These were then sealed in separate polyethylene bags for laboratory determination of moisture content and specific gravity. The first disk was at stump height and the remainder at 5-foot intervals measured from ground level for trees 5 inches dbh and larger and at 3-foot intervals for trees smaller than 5 inches dbh. All limbs, including leaves, were weighed on 84 of the trees.

In the laboratory, both wood and bark moisture content and specific gravity were determined as follows:

1. Wood and bark were separated with a hammer and chisel.
2. Each component was weighed green.
3. Both wood and bark were soaked in water for at least an hour to ensure complete swelling.
4. Volumes were obtained by immersion (Heinrichs and Lassen 1970).
5. Wood and bark were dried in a forced-air oven at 105°C for at least 48 hours.
6. Wood or bark moisture content = $$\frac{\text{green weight} - \text{ovendry weight}}{\text{ovendry weight}}.$$
7. Specific gravity = $$\frac{\text{ovendry wood or bark weight (g)}}{\text{green wood or bark volume (cm}^3\text{)}}.$$

Average tree moisture content and specific gravity were calculated from weighted averages of the disk moisture contents and specific gravities; each disk specific gravity or moisture content was weighted by its squared average diameter.

Taper functions (Schlaegel 1981, Schlaegel and Willson 1983) of the form

$$Y = b_1(X^1 - 1) + b_2(X^2 - 1) + \ldots + b_p(X^p - 1)$$

where

Y = d/D,
d = diameter at height h on the bole,
D = dbh,

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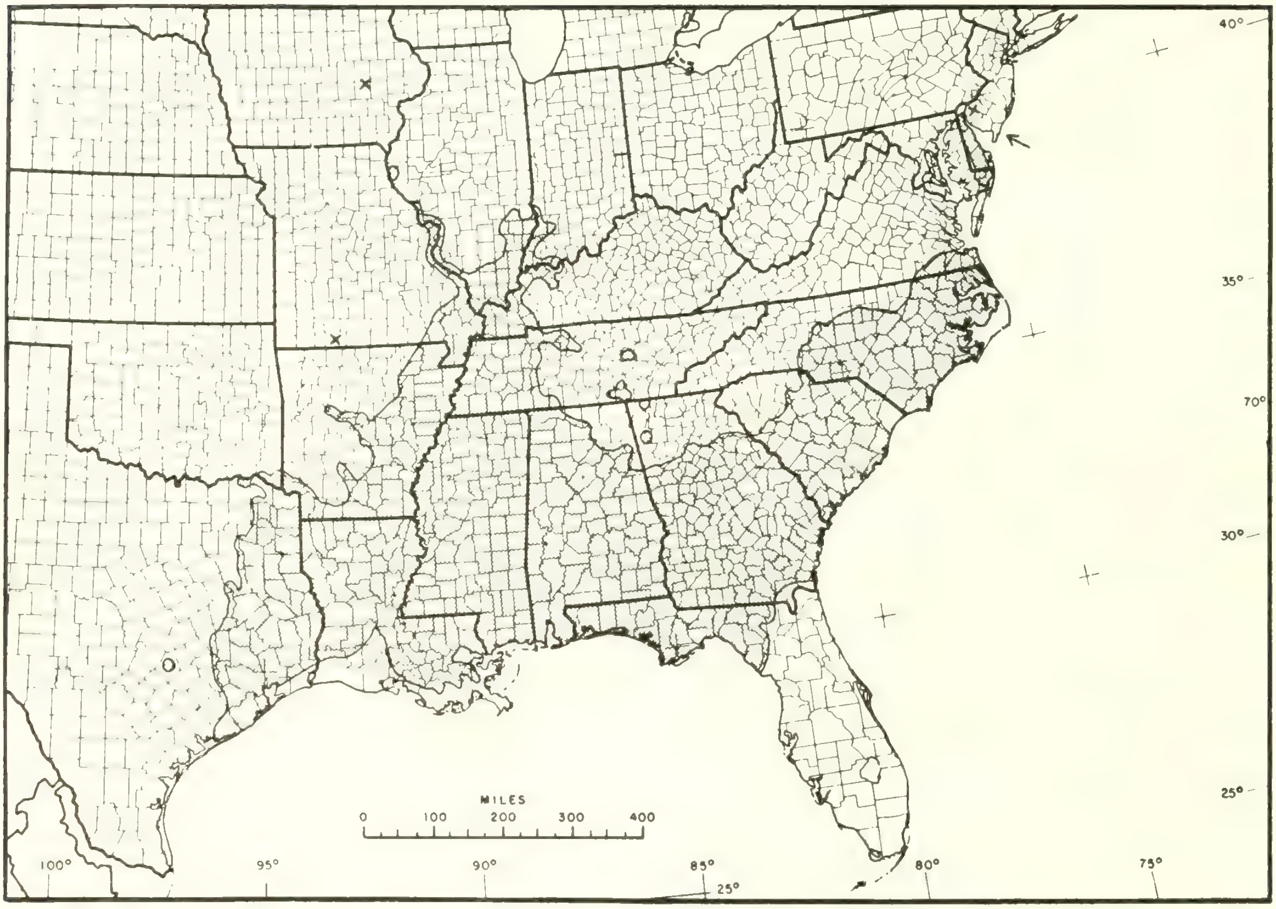

Figure 1.—*The range of overcup oak (Fowells 1965). (F-506651)*

$X = h/H$,
h = height from ground to a specific measurement point,
H = total height,
b_i = coefficients estimated for each tree by linear regression; $i = 1, 2, \ldots p$; $4 \leq p \leq 7$,

were calculated for each tree, both inside and outside bark. Cubic-foot volumes were obtained for each tree by integrating the taper function to heights of specific top diameters to obtain both total and merchantable bole volumes. Bole green and dry weights were calculated from estimated tree volume and weighted average tree density and moisture content.

Allometric regression equations were used to estimate volume, green weight, and dry weight of bole wood, bole wood plus bark, and bole wood plus bark plus limbs.

RESULTS

Characteristics of the trees used in this study are:

	Average	Range
Age *(years)*	87	7 – 225
Dbh *(in)*	14.0	0.8 – 34.0
Total height *(ft)*	64	9 – 100
Wood moisture content *(percent)*	87	33 – 124
Bark moisture content *(percent)*	102	62 – 296
Wood specific gravity	0.564	0.473 – 0.721
Bark specific gravity	0.388	0.266 – 0.558
Wood + bark green density *(lb/ft³)*	62.68	53.79 – 73.93
Wood + bark dry density *(lb/ft³)*	33.29	26.42 – 38.28
Wood + bark moisture content *(percent)*	89	41 – 140
Wood + bark specific gravity	0.533	0.423 – 0.613

Individual tree volumes and weights were fitted to the allometric model:

$$\mathrm{Ln}(Y) = b_0 + b_1\,\mathrm{Ln}(D^2H) \qquad (1)$$

where

Y = the volume or weight variable of interest,
Ln is a natural logarithm;
b_0 and b_1 are coefficients estimated from the data.

Estimates of the coefficients b_0 and b_1 are presented in table 1 for predicting cubic foot volume and green and dry weight of bole wood, bole bark, total bole, and total tree excluding leaves. Additional statistics presented are the component average, fit index, regression standard error of estimate ($\hat{S}_e$) based on residuals after converting to actual units, and coefficient of variation (C.V.) of predictions in arithmetic units. Fit index, which is similar to R^2, is used to judge equation efficiency when the dependent variable has been transformed (Farrar 1978) and is calculated in untransformed units from the total and residual sums of squares.[1] The fit index and R^2 are equal when a simple linear regression analysis is performed on an untransformed dependent variable.

Fit indices range from 0.945 for dry total tree weight to 0.988 for green bole wood weight. A fit index of 1.0 indicates that predictions can be made without error with the data used to fit the model; a value close to 1 is desirable. Coefficients of variation, which are indices of relative precision of prediction, range from 27.8 percent for dry total tree weight to 12.9 percent for green bole wood weight.

Using measures of individual tree dbh and total height, estimates can be made using table 1 for tree volume (given in table 2), green weight (given in table 3), and dry weight (given in table 4) for bole wood, bole wood plus bark, and for bole wood plus bark plus limbs excluding leaves.

The equations were developed using trees from a limited geographic range compared to the total range. Therefore, predictions may be less precise when the equations are applied in other parts of the range. Using an upper bole diameter measurement in addition to dbh as described later should alleviate this problem.

MERCHANTABLE BOLE ESTIMATES

The merchantable bole is defined as the tree bole from a 1-foot stump to a specified top diameter, ignoring limbs. Merchantable bole volume or weight can be expressed as a proportion of the total bole by a generalized form of the logistic model

$$R_I = (1.0 + e^{f(X)})^{-1} \quad (2)$$

where

R_I = ratio of merchantable bole volume or weight to total bole volume or weight, where I = top outside bark diameter of merchantable bole,
$X = (D - d_I)/D$,
D = tree dbh outside bark, and
d_I = outside bark top diameter.

For a specific top diameter, the ratio of merchantable bole to total bole is the same for volume, green weight, dry weight, and inside and outside bark (Schlaegel and Willson 1983).

Model 2 was fitted to the overcup oak data for trees ≥ 4.6 inches dbh, with $f(X) = b_0 + b_1X + b_2X^2 + b_3X^3 + b_4X^4$. Inverting (2) and taking the natural logarithm results in

$$\mathrm{Ln}\left(\frac{1 - R_I}{R_I}\right) = b_0 + b_1X + b_2X^2 + b_3X^3 + b_4X^4;$$

this was solved using multiple linear regression techniques giving:

$$R_I = [1.0 + \mathrm{EXP}\,(0.64378 + 16.57000\,X - 102.69489\,X^2 + 158.52166\,X^3 - 82.99971\,X^4)]^{-1} \quad (3)$$

with fit index = 0.953 and $\hat{S}_e = 0.042$; EXP is the base of the natural logarithm and equals 2.71828.

Volume or weight to any top diameter (V_I) is found by multiplying the ratio estimate obtained from (3) by a total bole volume or weight estimate from either table 2, 3, or 4:

$$V_I = R_I \cdot V_T,$$

where V_T is the total bole volume or weight of interest.

IMPROVED TOTAL BOLE ESTIMATES

The precision of the merchantable bole estimate depends upon accuracy in measuring total bole. Total bole estimates can be significantly improved by measuring one or two additional diameters. Tables 5 and 6 give regression statistics for total bole volume and weight under two different model forms:

$$\mathrm{Ln}(Y) = b_0 + b_1\,\mathrm{Ln}(D \cdot D_{1/3} \cdot H) \quad (4)$$

and

$$\mathrm{Ln}(Y) = b_0 + b_1\,\mathrm{Ln}[(D \cdot D_{1/2} + D^2_{1/4}) \cdot H] \quad (5)$$

where D, H, and Y are as defined previously, and $D_{1/3}$, $D_{1/2}$, and $D_{1/4}$ are diameters measured outside the bark at one-third, one-half, and one-fourth the total height.

Statistics from tables 5 and 6 show the significant ($\alpha = 0.05$) improvement over the previous D^2H equations of table 1. Measuring one additional diameter at one-third the tree height reduces $\hat{S}_e$ for bole wood volume, total bole volume, total green bole weight, and total dry bole weight by 34, 38, 25, and 21 percent, respectively. Other standard errors are reduced but not significantly.

Measuring two upper bole diameters at one-fourth and one-half total height will result in further significant increases in precision. Improvements over the D^2H model range from 20 to 61 percent for bole wood and total bole and from 7 to 18 percent for bark.

Taking additional bole measures means a higher inventory cost, since more time will be spent at each tree, but most of the inventory cost is in traveling to the candidate tree. Data presented in this paper allow total and merchantable bole estimates to be made with high reliability. Each user has to decide when increased precision is needed and whether the need offsets the higher cost.

---

[1] $FI = \{1 - [\Sigma(Y_i - \hat{Y}_i)^2] / [\Sigma(Y_i - \bar{Y})^2]\}$

LOCAL VOLUME TABLES

There are many occasions when the only tree variable available is dbh, or perhaps only a rough estimate of tree volume or weight is needed. In these cases a local volume table will suffice. Table 7 gives the statistics needed for estimating by the local volume table technique. However, it must be realized that estimation precision may be considerably lessened. The local volume or weight model is

$$\mathrm{Ln}(Y) = b_0 + b_1\,\mathrm{Ln}(D^2). \qquad (6)$$

CALCULATING CONFIDENCE LIMITS

Confidence limits ((1 − α) percent confidence limits) of individual predictions can be calculated using statistics presented in table 8. Clark et al. (1980) used the technique of Land (1972) to estimate approximate confidence limits for lognormal means of scarlet oak:

$$Y_{U.L.} = \mathrm{EXP}\left\{\mathrm{Ln}(Y) \pm Z_{\alpha/2}\left[S^2_{y\cdot x}\left[\frac{1}{n} + \frac{(X-\bar{X})^2}{\Sigma(X-\bar{X})^2}\right] + \frac{S^4_{y\cdot x}}{2(n+1)}\right]^{1/2}\right\}$$

where:

$Y_{U.L.}$ = upper and lower limits for Y,

EXP = base of natural logarithm; EXP = e = 2.71828,

Y = predicted volume or weight of component,

$Z_{\alpha/2}$ = value for the upper α/2 percentage point from the standard normal table,

$S_{y\cdot x}$ = standard error of estimate for prediction equation,

n = number of observations used to develop the equation,

$\bar{X}$ = sample mean of Ln(X),

$\Sigma(X-\bar{X})^2$ = corrected sum of squares for Ln(X),

X = $\mathrm{Ln}(D^2H)$; D = dbh and H = total height of tree for which Y is predicted.

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Table 1.—*Regression statistics for predicting overcup oak volumes and weights using dbh and total height*[1]

Component	Average Y	b_0	b_1	Fit index[2]	$\hat{S}_e$[3]	C.V. percent[4]
			Volume *(cubic feet)*			
Bole wood	40.5	−6.121	0.97357	0.986	5.53	13.7
Bole bark	5.7	−6.592	0.83522	0.965	1.10	19.3
Total bole	46.2	−5.709	0.94682	0.986	6.27	13.6
Total tree, excluding leaves	72.2	−5.772	0.98670	0.948	19.62	27.2
			Green weight *(pounds)*			
Bole wood	2666	−2.008	0.98142	0.988	344	12.9
Bole bark	277	−2.699	0.83346	0.963	55	19.9
Total bole	2943	−1.657	0.95682	0.987	383	13.0
Total tree, excluding leaves	4604	−1.729	0.99737	0.950	1217	26.4
			Dry weight *(pounds)*			
Bole wood	1401	−2.541	0.97131	0.981	221	15.8
Bole bark	153	−3.765	0.87747	0.961	33	21.3
Total bole	1554	−2.282	0.95592	0.982	239	15.4
Total tree, excluding leaves	2432	−2.343	0.99535	0.945	677	27.8

[1] Volumes and weights of trees from a 1-foot stump to the tree tip, using $\mathrm{Ln}(Y) = b_0 + b_1\,\mathrm{Ln}(D^2H)$; D = dbh, H = total tree height.

[2] Fit index = $1.0 - [\Sigma(Y - \hat{Y})^2 / \Sigma(Y - \bar{Y})^2]$, using untransformed values.

[3] $\hat{S}_e = [\Sigma(Y - \hat{Y})^2 / (n - 2)]^{1/2}$, using untransformed values.

[4] Coefficient of variation = $100\,\hat{S}_e / \bar{Y}$.

Table 2.—*Cubic-foot volume for overcup oak bole wood, bole wood plus bark, and total tree*[1]

	Total height in feet										
Dbh	10	20	30	40	50	60	70	80	90	100	110
inches	*cubic feet*										
1	0.02[2]	0.04									
	0.03[3]	0.06									
	0.03	0.06									
2	0.08	0.16	0.23								
	0.11	0.21	0.31								
	0.12	0.23	0.35								
3		0.34	0.51	0.68	0.84						
		0.45	0.66	0.87	1.08						
		0.52	0.78	1.04	1.29						
4		0.60	0.90	1.18	1.47	1.76					
		0.78	1.15	1.51	1.86	2.21					
		0.92	1.38	1.83	2.28	2.73					
5			1.38	1.83	2.27	2.72					
			1.75	2.30	2.84	3.37					
			2.14	2.84	3.54	4.24					
6				2.61	3.24	3.87	4.50				
				3.24	4.01	4.76	5.51				
				4.07	5.07	6.07	7.07				
7				3.52	4.38	5.23	6.07				
				4.34	5.36	6.38	7.38				
				5.52	6.88	8.23	9.58				
8				4.57	5.68	6.78	7.88				
				5.59	6.91	8.21	9.50				
				7.18	8.95	10.70	12.50				
9				5.75	7.14	8.53	9.91	11.3			
				6.99	8.63	10.30	11.90	13.5			
				9.06	11.30	13.50	15.70	17.9			
10				7.06	8.77	10.5	12.2	13.9			
				8.53	10.50	12.5	14.5	16.4			
				11.10	13.90	16.6	19.4	22.1			
11					10.6	12.6	14.6	16.7			
					12.6	15.0	17.4	19.7			
					16.8	20.1	23.4	26.7			
12					12.5	14.9	17.3	19.8			
					14.9	17.7	20.5	23.2			
					19.9	23.8	27.8	31.7			
13					14.6	17.4	20.3	23.1	25.9		
					17.3	20.6	23.8	27.0	30.2		
					23.3	27.9	32.5	37.1	41.7		
14					16.9	20.2	23.4	26.7	29.9		
					19.9	23.7	27.4	31.1	34.8		
					27.0	32.3	37.6	42.9	48.2		
15					19.3	23.1	26.8	30.5	34.2	37.9	
					22.7	27.0	31.2	35.4	39.6	43.8	
					30.9	37.0	43.1	49.2	55.3	61.3	
16					21.9	26.1	30.4	34.6	38.8	43.0	
					25.7	30.5	35.3	40.1	44.8	49.5	
					35.1	42.1	49.0	55.9	62.8	69.6	
17						29.4	34.2	38.9	43.7	48.4	
						34.2	39.6	44.9	50.2	55.5	
						47.4	55.2	63.0	70.7	78.5	
18						32.9	38.2	43.5	48.8	54.1	
						38.1	44.1	50.1	56.0	61.8	
						53.1	61.8	70.5	79.2	87.9	

Table 2.—*Cubic-foot volume for overcup oak bole wood, bole wood plus bark, and total tree—(Continued)*

	Total height in feet										
Dbh	10	20	30	40	50	60	70	80	90	100	110
inches	*cubic feet*										
19						36.5	**42.4**	48.3	**54.2**	60.1	
						42.2	**48.9**	55.5	**62.0**	68.5	
						59.0	**68.7**	78.4	**88.1**	97.8	
20						40.4	46.9	**53.4**	59.9	66.4	
						46.5	53.9	**61.1**	68.3	75.5	
						65.3	76.1	**86.8**	97.5	108.0	
21						44.4	51.6	**58.7**	**65.9**	73.0	
						51.0	59.1	**67.0**	**74.9**	82.8	
						71.9	83.8	**95.6**	**107.0**	119.0	
22						48.6	**56.5**	**64.3**	**72.1**	79.9	
						55.7	**64.5**	**73.2**	**81.8**	90.4	
						78.9	**91.8**	**105.0**	**118.0**	131.0	
23						53.0	61.6	**70.1**	**78.7**	87.2	
						60.6	70.2	**79.6**	**89.0**	98.4	
						86.1	100.0	**114.0**	**128.0**	143.0	
24						57.6	66.9	**76.2**	**85.5**	94.7	
						65.7	76.1	**86.3**	**96.5**	107.0	
						93.6	109.0	**124.0**	**140.0**	155.0	
25							72.4	**82.5**	**92.5**	103	112
							82.2	**93.3**	**104.0**	115	126
							118.0	**135.0**	**151.0**	168	185
26							78.2	**89.0**	100	**111**	121
							88.5	**100.0**	112	**124**	136
							128.0	**146.0**	164	**182**	199
27							84.2	**95.8**	**107**	119	131
							95.1	**108.0**	**121**	133	146
							138.0	**157.0**	**176**	196	215
28							90.3	103	115	128	140
							102.0	116	129	143	156
							148.0	169	189	210	231
29							96.7	110	124	137	150
							109.0	124	138	153	167
							158.0	181	203	225	247
30							103	118	**132**	146	160
							116	132	**147**	163	178
							169	193	**217**	241	265
31							110	125	**141**	156	171
							124	140	**157**	173	189
							181	206	**231**	257	282
32							117	133	**150**	166	182
							131	149	**166**	184	201
							192	219	**246**	273	300
33							124	142	159	176	193
							139	158	176	195	213
							204	233	262	291	319
34							132	150	168	**187**	205
							147	167	187	**206**	226
							217	247	278	**308**	339
35							139	159	178	197	217
							155	176	197	218	238
							230	262	294	326	359
36							147	168	188	209	229
							164	186	208	230	251
							243	277	311	345	379

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[1] Tree volume from a 1-foot stump to the tree tip.

[2] The three vertical figures for each dbh give volumes of bole wood first, bole wood plus bark second, and total tree (bole wood plus bark plus limbs excluding leaves) last.

[3] Boldface numbers span the range of the data.

Table 3.—*Green weight in pounds for overcup oak bole wood, bole wood plus bark, and total tree*[1]

Dbh	Total height in feet										
	10	20	30	40	50	60	70	80	90	100	110
inches	*pounds*										
1	1.3[2]	2.5									
	1.7[3]	3.4									
	1.8	3.5									
2	5.0	9.9	15								
	6.5	12.6	19								
	7.0	14.0	21								
3		22	33	43	54						
		27	40	53	66						
		32	47	63	79						
4		39	57	76	95	113					
		48	70	92	114	136					
		56	84	112	139	167					
5			89	118	147	176					
			107	142	175	209					
			131	174	218	261					
6				169	210	251	293				
				201	248	296	343				
				251	313	376	438				
7				229	285	340	396				
				269	334	397	460				
				341	426	511	596				
8				297	370	442	514				
				348	431	513	594				
				445	556	667	778				
9				374	466	557	648	739			
				436	540	642	745	846			
				563	703	843	984	1124			
10				460	573	685	797	909			
				533	660	786	911	1035			
				695	868	1041	1214	1387			
11					691	826	961	1096			
					792	943	1093	1242			
					1049	1259	1468	1677			
12					820	980	1140	1300			
					936	1114	1291	1467			
					1248	1497	1746	1995			
13					959	1147	1334	1521	1708		
					1091	1298	1505	1710	1914		
					1464	1756	2048	2340	2632		
14					1109	1327	1543	1759	1975		
					1257	1496	1734	1970	2206		
					1698	2036	2375	2713	3051		
15					1270	1519	1767	2014	2261	2508	
					1434	1707	1979	2249	2517	2784	
					1948	2337	2725	3113	3501	3889	
16					1442	1724	2006	2286	2567	2846	
					1623	1932	2239	2544	2848	3150	
					2216	2658	3099	3541	3982	4423	
17						1942	2259	2575	2891	3206	
						2170	2514	2857	3198	3537	
						2999	3498	3996	4494	4992	
18						2172	2527	2881	3234	3587	
						2420	2805	3187	3568	3946	
						3361	3920	4478	5037	5595	

Table 3.—*Green weight in pounds for overcup oak bole wood, bole wood plus bark, and total tree—(Continued)*

	Total height in feet										
Dbh	10	20	30	40	50	60	70	80	90	100	110
inches						*pounds*					
19						2416	**2810**	3204	**3596**	3988	
						2684	**3111**	3535	**3956**	4376	
						3744	**4366**	4989	**5610**	6232	
20						2672	3108	**3543**	3977	4411	
						2961	3432	**3899**	4365	4827	
						4148	4837	**5526**	6215	6903	
21						2940	3420	**3899**	**4377**	4854	
						3251	3767	**4281**	**4792**	5300	
						4572	5331	**6091**	**6850**	7609	
22						3221	**3747**	**4272**	**4795**	5318	
						3554	**4118**	**4680**	**5238**	5793	
						5016	**5850**	**6683**	**7516**	8349	
23						3515	4089	**4661**	**5233**	5803	
						3869	4484	**5095**	**5703**	6308	
						5481	6392	**7303**	**8213**	9123	
24						3821	4445	**5068**	**5689**	6308	
						4197	4864	**5527**	**6187**	6843	
						5967	6958	**7950**	**8941**	9931	
25							4816	**5490**	**6163**	6835	7505
							5260	**5976**	**6689**	7399	8105
							7549	**8624**	**9699**	10774	11848
26							5201	**5930**	6656	**7381**	8105
							5670	**6442**	7211	**7976**	8737
							8163	**9326**	10488	**11651**	12812
27							5601	**6386**	**7168**	7949	8728
							6094	**6925**	**7751**	8573	9391
							8801	**10055**	**11309**	12562	13814
28							6016	6858	7699	8537	9374
							6533	7424	8309	9191	10068
							9464	10812	12159	13507	14854
29							6445	7347	**8248**	9146	10043
							6987	7939	**8887**	9829	10768
							10150	11596	**13041**	14486	15931
30							6888	7853	**8815**	9775	10734
							7456	8472	**9482**	10488	11489
							10860	12407	**13953**	15500	17045
31							7346	8375	**9401**	10425	11447
							7938	9020	**10096**	11167	12233
							11594	13246	**14897**	16547	18197
32							7818	8913	**10005**	11095	12183
							8436	9585	**10729**	11867	13000
							12352	14111	**15870**	17629	19387
33							8305	9468	10628	**11786**	12942
							8947	10167	11379	**12586**	13788
							13134	15005	16875	**18745**	20614
34							8806	10040	11270	**12498**	13723
							9473	10764	12048	**13326**	14599
							13940	15925	17911	**19895**	21879
35							9322	10627	11930	13299	14526
							10014	11378	12736	14087	15432
							14769	16873	18977	21079	23182
36							9852	11232	12608	13981	15352
							10568	12009	13441	14867	16286
							15623	17849	20074	22298	24522

[1] Tree weight from a 1-foot stump to the tree tip.

[2] The three vertical figures for each dbh give weights of bole wood first, bole wood plus bark second, and total tree (bole wood plus bark plus limbs excluding leaves) last.

[3] Boldface numbers span the range of the data.

Table 4.—*Dry weight in pounds for overcup oak bole wood, bole wood plus bark, and total tree*[1]

Dbh	Total height in feet										
	10	20	30	40	50	60	70	80	90	100	110
inches	*pounds*										
1	0.7[2]	1.4									
	0.9[3]	1.8									
	1.0	1.9									
2	2.8	5.6	8.2								
	3.5	6.7	9.9								
	3.8	7.5	11.3								
3		12	18	24	30						
		15	22	28	35						
		17	25	34	42						
4		21	32	42	52	62					
		25	37	49	61	72					
		30	45	60	74	89					
5			49	65	80	96					
			57	75	93	111					
			70	93	116	139					
6				92	114	137	159				
				107	132	157	182				
				134	167	200	233				
7				124	154	184	214				
				143	177	211	245				
				182	227	272	317				
8				161	200	239	277				
				185	229	272	316				
				237	296	355	414				
9				202	251	300	349	397			
				232	287	341	395	449			
				300	374	449	523	597			
10				248	309	368	428	487			
				283	351	417	484	550			
				370	462	553	645	737			
11					371	443	515	586			
					421	501	580	659			
					558	669	780	891			
12					440	525	610	694			
					497	591	685	779			
					664	796	927	1059			
13					514	613	712	811	909		
					579	689	799	907	1016		
					778	933	1088	1242	1397		
14					593	708	822	936	1050		
					667	794	920	1046	1170		
					902	1081	1261	1440	1619		
15					678	810	940	1071	1200	1330	
					761	906	1050	1193	1335	1477	
					1035	1240	1446	1652	1857	2062	
16					769	918	1066	1214	1361	1507	
					861	1025	1188	1350	1511	1671	
					1176	1410	1644	1878	2112	2345	
17						1032	1199	1365	1531	1696	
						1151	1334	1516	1696	1876	
						1591	1855	2119	2383	2646	
18						1154	1340	1526	1711	1895	
						1284	1488	1691	1892	2092	
						1783	2079	2374	2670	2965	

Table 4.—*Dry weight in pounds for overcup oak bole wood, bole wood plus bark, and total tree—(Continued)*

	Total height in feet										
Dbh	10	20	30	40	50	60	70	80	90	100	110
inches						*pounds*					
19						1282	**1489**	1695	**1900**	2105	
						1424	**1650**	1875	**2098**	2320	
						1986	**2315**	2644	**2973**	3302	
20						1416	1644	**1872**	2099	2325	
						1571	1820	**2068**	2314	2559	
						2199	2564	**2929**	3293	3657	
21						1557	1808	**2058**	**2308**	2557	
						1724	1998	**2270**	**2540**	2810	
						2424	2826	**3227**	**3629**	4030	
22						1704	**1979**	**2253**	**2526**	2798	
						1885	**2184**	**2481**	**2777**	3071	
						2659	**3100**	**3540**	**3981**	4421	
23						1857	2157	**2456**	**2754**	3051	
						2052	2377	**2701**	**3023**	3343	
						2905	3387	**3868**	**4349**	4830	
24						2018	2343	**2668**	**2991**	3314	
						2226	2579	**2930**	**3279**	3627	
						3162	3686	**4210**	**4734**	5257	
25							2537	**2888**	**3238**	3587	3935
							2788	**3168**	**3545**	3921	4295
							3998	**4566**	**5134**	5702	6269
26							2738	**3117**	3495	**3871**	4247
							3005	**3415**	3822	**4227**	4630
							4323	**4937**	5551	**6165**	6779
27							2946	**3354**	**3760**	4166	4570
							3230	**3670**	**4108**	4543	4976
							4660	**5322**	**5984**	6646	7307
28							3162	3599	4036	4470	4904
							3463	3934	4403	4870	5334
							5010	5722	6434	7145	7856
29							3385	3853	**4320**	4786	5250
							3703	4207	**4709**	5208	5705
							5372	6136	**6899**	7662	8424
30							3615	4116	**4614**	5112	5607
							3951	4489	**5024**	5556	6086
							5747	6564	**7381**	8197	9013
31							3853	4386	**4918**	5448	5976
							4207	4780	**5349**	5916	6480
							6135	7007	**7879**	8750	9621
32							4098	4665	**5231**	5794	6356
							4470	5079	**5684**	6286	6886
							6535	7464	**8393**	9321	10248
33							4350	4953	5553	**6151**	6748
							4741	5386	6028	**6667**	7303
							6948	7936	8923	**9910**	10896
34							4610	5248	5885	**6519**	7151
							5019	5703	6382	**7059**	7732
							7374	8422	9469	**10516**	11563
35							4877	5552	6225	6896	7565
							5305	6028	6746	7461	8173
							7812	8922	10032	11141	12250
36							5151	5865	6576	7284	7991
							5599	6361	7119	7874	8625
							8262	9437	10610	11784	12956

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[1] Tree weight from a 1-foot stump to the tree tip.

[2] The three vertical figures for each dbh give weights of bole wood first, bole wood plus bark second, and total tree (bole wood plus bark plus limbs excluding leaves) last.

[3] Boldface numbers span the range of the data.

Table 5.—*Regression statistics for predicting overcup oak bole volumes and weights using two bole diameter measurements and total height*[1]

Component	Average Y	b_0	b_1	Fit index[2]	$\hat{S}_e$[3]	C.V. percent[4]
			Volume *(cubic feet)*			
Bole wood	40.5	−6.023	0.99595	0.994	3.65*	9.0
Bole bark	5.7	−6.509	0.85457	0.969	1.04	18.3
Total bole	46.2	−5.615	0.96870	0.995	3.91*	8.5
			Green weight *(pounds)*			
Bole wood	2666	−1.908	1.00389	0.991	288	10.8
Bole bark	277	−2.623	0.85329	0.968	51	18.6
Total bole	2943	−1.562	0.97894	0.993	287*	9.7
			Dry weight *(pounds)*			
Bole wood	1401	−2.441	0.99347	0.987	187	13.3
Bole bark	153	−3.688	0.89855	0.968	29	19.2
Total bole	1554	−2.186	0.97795	0.989	188*	12.1

[1] Volumes and weights of trees from a 1-foot stump to the tree tip, using $\mathrm{Ln}(Y) = b_0 + b_1 \mathrm{Ln}(D \cdot D_{1/3} \cdot H)$; D = dbh, H = total tree height, $D_{1/3}$ = bole diameter outside bark at ⅓H.

[2] Fit index = $1.0 - [\Sigma(Y - Y)^2 / \Sigma(Y - \bar{Y})^2]$, using untransformed values.

[3] $\hat{S}_e = [\Sigma(Y - \hat{Y})^2 / (n - 2)]^{1/2}$, using untransformed values.

[4] Coefficient of variation = $100\, \hat{S}_e / \bar{Y}$.

*Significantly more precise by the F test than D^2H model; $\alpha = 0.05$.

Table 6.—*Regression statistics for predicting overcup oak bole volumes and weights using three bole diameter measurements and total height*[1]

Component	Average Y	b_0	b_1	Fit index[2]	$\hat{S}_e$[3]	C.V. percent[4]
			Volume *(cubic feet)*			
Bole wood	40.5	−6.708	1.10678	0.997	2.65*	6.5
Bole bark	5.7	−7.099	0.87258	0.970	1.02	17.9
Total bole	46.2	−6.282	0.98903	0.998	2.44*	5.3
			Green weight *(pounds)*			
Bole wood	2666	−2.598	1.02482	0.992	276^{+}	10.3
Bole bark	277	−3.216	0.87152	0.970	50	17.9
Total bole	2943	−2.236	0.99948	0.995	247^{+}	8.4
			Dry weight *(pounds)*			
Bole wood	1401	−3.123	1.01413	0.988	176^{+}	12.5
Bole bark	153	−4.314	0.91791	0.972	27^{+}	18.0
Total bole	1554	−2.859	0.99842	0.991	166^{+}	10.7

[1] Volumes and weights of trees from a 1-foot stump to the tree tip, using $\mathrm{Ln}(Y) = b_0 + b_1 \mathrm{Ln}[(D \cdot D_{1/2} + D^2_{1/4})H]$; D = dbh, H = total tree height, $D_{1/2}$ and $D_{1/4}$ = bole diameters outside bark at ½H and ¼H, respectively.

[2] Fit index = $1.0 - [\Sigma(Y - \hat{Y})^2 / \Sigma(Y - \bar{Y})^2]$, using untransformed values.

[3] $\hat{S}_e = [\Sigma(Y - \hat{Y})^2 / (n - 2)]^{1/2}$, using untransformed values.

[4] Coefficient of variation = $100\, \hat{S}_e / \bar{Y}$.

$^{+}$Significantly more precise by the F test than $D \cdot D_{1/3} \cdot H$ model; $\alpha = 0.05$.

*Significantly more precise by the F test than D^2H model; $\alpha = 0.05$.

Table 7.—*Local volume and weight equations for overcup oak*[1]

Component	Average Y	b_0	b_1	Fit index[2]	$\hat{S}_e$[3]	C.V. percent[4]
			Volume *(cubic feet)*			
Bole wood	40.5	−3.343	1.22924	0.969	8.38*	20.7
Bole bark	5.7	−4.214	1.05515	0.938	1.48*	25.9
Total bole	46.2	−3.011	1.19596	0.972	8.94*	19.3
Total tree, excluding leaves	72.2	−2.972	1.24788	0.961	16.93	23.4
			Green weight *(pounds)*			
Bole wood	2666	0.795	1.23887	0.959	628*	23.5
Bole bark	277	−0.338	1.05436	0.939	71*	25.7
Total bole	2943	1.069	1.20860	0.965	629*	21.4
Total tree, excluding leaves	4604	1.103	1.26121	0.957	1129	24.5
			Dry weight *(pounds)*			
Bole wood	1401	0.237	1.22573	0.952	357*	25.5
Bole bark	153	−1.282	1.11032	0.942	40*	25.9
Total bole	1554	0.446	1.20702	0.958	365*	23.5
Total tree, excluding leaves	2432	0.486	1.25829	0.951	639	26.3

[1] Volumes and weights of trees from a 1-foot stump to the tree tip, using $\mathrm{Ln}(Y) = b_0 + b_1\ \mathrm{Ln}(D^2)$; D = dbh.

[2] Fit index = 1.0 − $[\Sigma(Y - \hat{Y})^2 / \Sigma(Y - \bar{Y})^2]$, using untransformed values.

[3] $\hat{S}_e = [\Sigma(Y - \hat{Y})^2 / (n - 2)]^{1/2}$, using untransformed values.

[4] Coefficient of variation = $100\ \hat{S}_e / \bar{Y}$.

*Significantly less precise by the F test than D^2H model; $\alpha = 0.05$.

Table 8.—*Statistics for estimating confidence bounds for overcup oak predictions for the bole and total tree*

Independent variable – X	n	Mean of X	Corrected sum of squares for X[1]	$S_{y \cdot x}$ Standard error of estimate for tree components			
		Bole predictions			Wood	Bark	Total
$\mathrm{Ln}(D^2)$	88	4.575	316.468	Volume	0.1684	0.1927	0.1504
				Green weight	0.1812	0.2113	0.1595
				Dry weight	0.1963	0.2292	0.1725
$\mathrm{Ln}(D^2H)$	88	8.623	505.735	Volume	0.1216	0.1782	0.1190
				Green weight	0.1283	0.2244	0.1298
				Dry weight	0.1384	0.2474	0.1314
$\mathrm{Ln}(D \cdot D_{1/3} \cdot H)$	88	8.327	483.999	Volume	0.0796	0.1551	0.0697
				Green weight	0.0941	0.1943	0.0852
				Dry weight	0.1119	0.2126	0.0920
$\mathrm{Ln}[(D \cdot D_{1/2} + D^2_{1/4})H]$	88	8.829	464.587	Volume	0.0615	0.1446	0.0401
				Green weight	0.0834	0.1794	0.0639
				Dry weight	0.1060	0.1936	0.0761
		Total tree predictions				Total tree	
$\mathrm{Ln}(D^2)$	84	4.596	311.562	Volume		0.1618	
				Green weight		0.1722	
				Dry weight		0.1820	
$\mathrm{Ln}(D^2H)$	84	8.654	497.862	Volume		0.1782	
				Green weight		0.1837	
				Dry weight		0.1838	

[1] $\Sigma(X - \bar{X})^2$ in base e logarithmic units.

APPENDIX

Examples Using the Equations

In this section examples are presented to illustrate use of the equations. The following tabulation gives data used to illustrate equation use:

$D = 21.7$ in.
$H = 75.0$ ft.
$D_{1/4} = 15.5$ in.
$D_{1/3} = 14.8$ in.
$D_{1/2} = 11.5$ in.

Bole wood volume (V) is calculated using $X = D^2H$ and the parameter estimates from table 1 as follows:

$$\begin{aligned}
\mathrm{Ln}(V) &= b_0 = b_1 \,\mathrm{Ln}(D^2H) \\
&= -6.121 + 0.97357 \,\mathrm{Ln}\,(21.7 \times 21.7 \times 75.0) \\
&= -6.121 + 0.97357 \,\mathrm{Ln}\,(35316.75) \\
&= -6.121 + 0.97357\,(10.472) \\
&= -6.121 + 10.195 \\
\mathrm{Ln}(V) &= 4.074 \\
V &= e^{4.074}\text{; bole wood volume} = 58.8 \text{ ft}^3.
\end{aligned}$$

To calculate total green bole weight (W) using $X = D \cdot D_{1/3} \cdot H$ and the parameter estimates from table 5:

$$\begin{aligned}
\mathrm{Ln}(W) &= b_0 + b_1 \,\mathrm{Ln}\,(D \cdot D_{1/3} \cdot H) \\
&= -1.562 + 0.97894 \,\mathrm{Ln}\,(21.7 \times 14.8 \times 75.0) \\
&= -1.562 + 0.97894 \,\mathrm{Ln}\,(24087.00) \\
&= -1.562 + 0.97894\,(10.089) \\
&= -1.562 + 9.877 \\
\mathrm{Ln}(W) &= 8.315 \\
W &= e^{8.315}\text{; total bole green weight} = 4085 \text{ lb.}
\end{aligned}$$

To calculate bole dry weight (W) using $X = [(D \cdot D_{1/2} + D^2_{1/4})H]$ and the parameter estimates from table 6:

$$\begin{aligned}
\mathrm{Ln}(W) &= b_0 + b_1 \,\mathrm{Ln}\,[(D \cdot D_{1/2} + D^2_{1/4})H] \\
&= -2.859 + 0.99842 \,\mathrm{Ln}\,[(21.7 \times 11.5 + 15.5 \times 15.5) \times 75.0] \\
&= -2.859 + 0.99842 \,\mathrm{Ln}\,[(249.55 + 240.25) \times 75.0] \\
&= -2.859 + 0.99842 \,\mathrm{Ln}\,[489.80 \times 75.0] \\
&= -2.859 + 0.99842 \,\mathrm{Ln}\,[36735.00] \\
&= -2.859 + 0.99842\,(10.511) \\
&= -2.859 + 10.494 \\
\mathrm{Ln}(W) &= 7.635 \\
W &= e^{7.635}\text{; total bole dry weight} = 2069 \text{ lb.}
\end{aligned}$$

Merchantable bole estimates to, say, an 8-inch top are calculated using equation 3 to estimate the merchantable portion of the bole and then multiplying that proportion (R8) by the predicted bole estimate of interest. Letting $DI = 8.0$, $X = [(21.7 - 8.0)/21.7]$, or $X = 0.631$, and from (3):

$$\begin{aligned}
R8 &= [1.0 + \mathrm{EXP}\,(0.64378 + 16.57000\,(0.631) - 102.69489\,(0.631)^2 + 158.52166\,(0.631)^3 - 82.99971\,(0.631)^4)]^{-1} \\
&= [1.0 + \mathrm{EXP}\,(0.64378 + 16.57000\,(0.631) - 102.69489\,(0.39816) + 158.52166\,(0.25124) - 82.99971\,(0.15853))]^{-1} \\
&= [1.0 + \mathrm{EXP}\,(0.64378 + 10.45567 - 40.88900 + 39.82698 - 13.15794)]^{-1} \\
&= [1.0 + \mathrm{EXP}\,(-3.12051)]^{-1} \\
&= [1.0 + 0.04413]^{-1} \\
&= [1.04413]^{-1} \\
R8 &= 0.958.
\end{aligned}$$

Then bole wood volume to an 8-inch top (V8) can be calculated:

$$\begin{aligned}
V8 &= (R8)(\text{predicted total bole wood volume}) \\
&= (0.958)(58.8) \\
&= 56.3 \text{ ft}^3.
\end{aligned}$$

Of course, total bole volumes or weights can be calculated using any one of the three sets of parameter estimates given in tables 1, 5, or 6. Then any of these total bole calculations can be used with the estimate of merchantable proportion to calculate merchantable bole values. The choice of which set of equations to use is left to the user, who must balance inventory precision against inventory cost.

Schlaegel, Bryce E. Overcup oak volume and weight tables. Res. Pap. SO-207. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1984. 14 p.

A sample of 88 trees from the Mississippi Delta is used to construct volume and weight tables for overcup oak.

Additional keywords: *Quercus lyrata,* merchantable bole estimates, biomass.

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Geographic Variation Patterns in Seed and Nursery Characteristics of Black Cherry

John A. Pitcher

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SUMMARY

In a range-wide study, weight, size, endocarp weight, and kernel weight of black cherry *(Prunus serotina* Ehrh.) seeds varied clinally with latitude; those from farther north were larger in all respects. These characteristics, however, were not related to germination or seedling growth of the half-sib families through the first year in a Southern nursery. Seedling height was not related to latitude of origin. There was a strong association between leaf size, leaf area, and height growth. Results are discussed in view of the evolutionary development of the species.

Geographic Variation Patterns in Seed and Nursery Characteristics of Black Cherry

John A. Pitcher

INTRODUCTION

Knowledge of the range of values for selected traits and the description of their geographic distribution are basic types of information required in tree breeding and genetic improvement programs. Thor (1977) points out that failure of the breeder to obtain substantial information on provenance variation increases the possibility of selecting trees from inferior populations.

In 1979 and 1980, black cherry *(Prunus serotina* Ehrh.) seeds were collected from many locations throughout a major part of the natural range of the species (fig. 1). The purpose was to provide seed for provenance evaluation as requested by scientists of the Instituto Nacional de Investigaciones Agrarias at Lourizan, Spain. This collection activity provided sufficient seeds to establish additional tests in the United States.

MATERIALS AND METHODS

Black cherry fruits were collected from 1 to 12 trees in 64 separate locations over the 2-year period (table 1). Although black cherry is considered to be entirely self-incompatible (Knight 1969) and therefore there is no possibility of half-sib matings (Mather 1973), collecting from adjacent trees was avoided. No special effort was made to select superior phenotypes. Seed was harvested by many different cooperators. While personal biases may have influenced the choice of each parent tree, the effect of such bias was diluted by the large number of contributors to the study. Each collection area varied in size, depending on the number of seed-bearing trees in the locality.

Fruits or depulped seeds were shipped to the Forestry Sciences Laboratory at Starkville, Mississippi. Seeds were extracted by maceration in water using a blender at low speed for 10 to 15 seconds. Pulp and empty seeds were removed by screening and flotation. Cleaned seeds were dried at room temperature overnight before storage at 3° to 5°C in polyethylene bags.

A single random sample of 100 seeds from each tree was used to estimate the mean seed weight. Source means were derived from simple arithmetic sums of individual samples within the collection point. Oven-dry kernel and endocarp weights were obtained from 100-seed samples in each of the seedlots collected in 1979.

Following stratification, seeds collected in 1979 were sown directly into nursery seedbeds at the Forestry Sciences Laboratory in April 1980. Highly erratic germination in the seedbeds prompted the decision to abandon this material and repeat the test the following year. Seeds collected in 1980, as well as some from the 1979 collection, were stratified, sown in peat pots in a greenhouse, and then transplanted into the nursery beds in May 1981. This gave a satisfactory seedling density. One hundred and thirty-six seedlots were sown in 1981, 30 from 1979 collections and 106 from 1980 collections. Of these, 82 lots from 35 origins had sufficient germinants for the nursery study. A randomized complete block design containing six replications of 82 families arranged in 8-tree row plots was used. Germination and measurements of total height and leaf length and width were recorded for each family.

Using the SYMAP[1] computer program, seed weight data were plotted to generate a map illustrating seed weight distribution throughout the population sampled. Analysis of variance and correlation analyses were used on fresh weight; oven-dry endocarp and kernel weights; leaf length, width, and area; and germination and seedling height. A significance level of $P \leq 0.05$ was used in all tests. Using weather records from the National Climatic Center in Asheville, North Carolina, 12 climatic variables and three geographic factors were correlated with seed weight.

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[1] Synagraphic Mapping System, Laboratory for Computer Graphics and Spatial Analysis, Harvard Graduate School of Design, Cambridge, Massachusetts.

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Table 1.—*Seed origin data for black cherry seed collections, 1979 – 1980*

Seed origin number	No. of seed lots	County	State	Latitude	Longitude	Mean weight of 100 seeds (grams)	No. in nursery test
1	5	Goodhue	MN	44.5	92.6	13.0	0
2	8	Oneida	WI	45.6	89.4	11.8	0
3	3	Alger	MI	46.3	86.8	14.2	0
4	5	McKean	PA	41.8	78.7	8.5	3
5	4	Warren	PA	41.7	79.1	10.5	3
6	5	Kalamazoo	MI	42.2	85.4	11.8	0
7	5	Cassopolis	MI	42.0	86.0	10.6	0
8	10	Dane	WI	43.0	89.5	12.5	0
9	2	Allamkee	IA	43.0	92.0	10.5	0
10	8	Marshall	IA	41.8	93.2	10.2	2
11	3	McLean	IL	40.5	89.0	9.0	0
12	3	Tippecanoe	IN	40.4	86.9	11.3	0
13	2	Miami	OH	40.1	84.1	9.4	2
14	5	Delaware	OH	40.3	83.0	9.6	3
15	6	Tucker	WV	39.1	79.6	9.2	5
16	5	Monroe	IN	39.0	86.6	9.9	0
17	3	Bond	IL	38.8	89.5	8.5	0
18	8	Linn	KS	38.3	95.0	10.0	1
19	4	Texas	MO	37.3	92.0	8.8	1
20	12	Jackson	IL	37.8	89.2	8.0	0
21	3	Hardin	IL	37.5	88.3	8.7	0
22	1	McCracken	KY	37.0	88.7	7.2	0
23	3	Hopkins	KY	37.3	87.5	8.2	1
24	2	Christian	KY	36.8	87.5	7.2	0
25	1	Hardin	KY	37.8	86.0	7.9	0
26	3	Monroe	WV	37.6	80.4	9.1	3
27	3	Montgomery	VA	37.2	80.3	9.8	3
28	5	Wake	NC	35.7	78.8	6.3	4
29	2	Jones	NC	35.0	77.5	9.2	1
30	3	Montgomery	NC	35.4	79.9	5.6	0
31	3	Johnson	TN	36.5	81.8	9.1	2
32	2	Cherokee	NC	35.2	84.0	5.6	0
33	6	Rabun	GA	34.9	83.4	6.3	3
34	8	Anderson	TN	36.1	84.1	5.1	5
35	7	Murray	GA	34.8	84.7	5.9	1
36	2	Maury	TN	35.4	87.2	6.2	0
37	3	Dickson	TN	36.0	87.5	6.6	0
38	2	Montgomery	TN	36.5	87.3	6.0	0
39	4	Henderson	TN	35.8	88.4	5.4	0
40	3	Hardeman	TN	35.4	89.0	5.5	1
41	4	Lauderdale	TN	35.8	89.5	5.0	0
42	2	Boone	AR	36.4	93.0	7.0	2
43	6	Garland	AR	34.5	93.3	6.3	4
44	5	Marshall	MS	34.6	89.5	5.8	3
45	6	Carroll	MS	33.4	89.9	4.7	1
46	9	Oktibbeha	MS	33.4	88.8	6.6	3
47	4	Winston	AL	34.2	87.3	6.0	0
48	3	Talladega	AL	33.4	86.2	5.3	0
49	2	Lee	AL	32.6	85.5	5.5	0
50	3	Henry	GA	33.4	84.2	5.2	0
51	4	Clarke	GA	34.0	83.3	5.0	3
52	3	Greenwood	SC	34.1	82.2	5.2	3
53	8	Charleston	SC	33.1	79.6	7.5	2
54	3	Dodge	GA	32.1	83.2	5.3	2
55	2	Clay	FL	30.0	82.0	6.1	0
56	7	Alachua	FL	29.7	82.3	7.8	2
57	1	Columbia	FL	30.2	82.6	7.7	1
58	3	Liberty	FL	30.3	85.1	5.5	0
59	2	Covington	AL	31.1	86.6	5.2	2
60	6	Harrison	MS	30.6	89.0	4.6	4
61	3	Amite	MS	31.2	90.7	4.1	3
62	1	Scott	MS	32.3	89.2	4.7	1
63	9	Union	LA	32.9	92.2	5.7	1
64	2	Jasper	TX	30.9	94.0	5.6	0

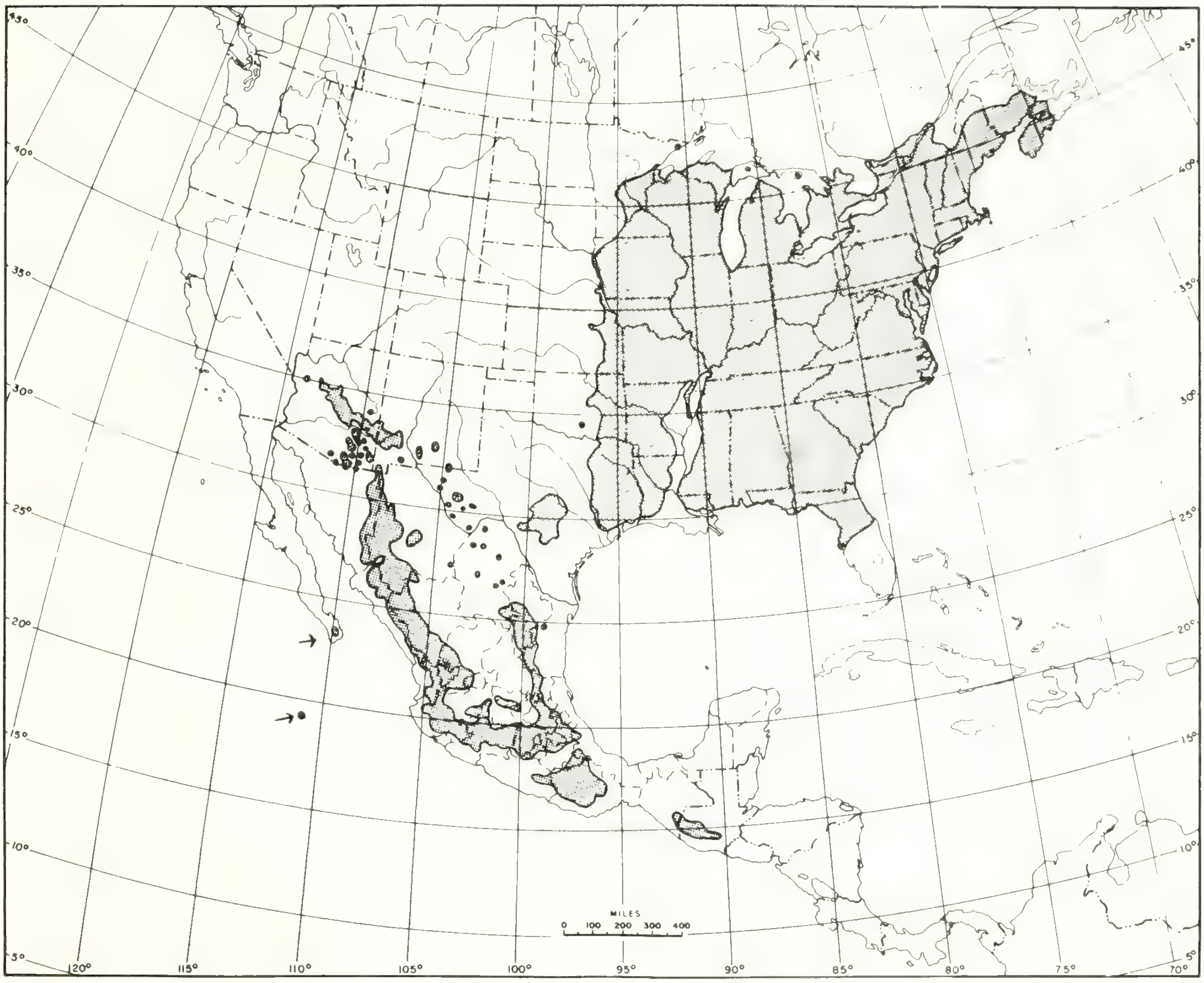

Figure 1.—*The range of black cherry. From Little, E. L., Jr. Atlas of United States Trees. U.S. Department of Agriculture, Forest Service, Misc. Publ. No. 1146, Vol. 1. 1971.*

RESULTS

Seed Weight

The sample mean weight of 7.89 grams per 100 seeds agrees reasonably well with the value of 8.45 grams per 100 seeds listed in the standard reference, Seeds of Woody Plants in the United States (1974), but is much closer to the value of 8.01 grams per 100 seeds reported by Cech and Kitzmiller (1968). These lower values may be due to the inclusion of many samples from outside the "commercial" range of black cherry. Mean seed weights were not significantly different between years of collection.

Figure 2 depicts the distribution of black cherry seed weights as generated by the SYMAP program. In producing the map, the SYMAP program interpolates between adjacent data points. Each data point has an effect that is inversely proportional to the square of the distance between it and any adjacent data point values. Class intervals were one gram (e.g., 7.5 to 8.4 were the lower and upper limits for the 8.0 gram class).

The map clearly illustrates that black cherry seed weight increases with latitude. A distinct "valley" appears, but there are no obvious peaks. The valley follows the Atlantic Coastal Plain from central Georgia to the Chesapeake Bay area, paralleling the eastern slopes of the Appalachian Mountains. Atlantic coastal seed origins were heavier than those from the interior only for a relatively short distance inland. The broad Gulf Coastal Plain shows remarkably uniform seed weights over most of its area. Seed samples were not obtained from the New England and some of the Mid-Atlantic regions, so these areas are shown essentially blank. Despite these variations and anom-

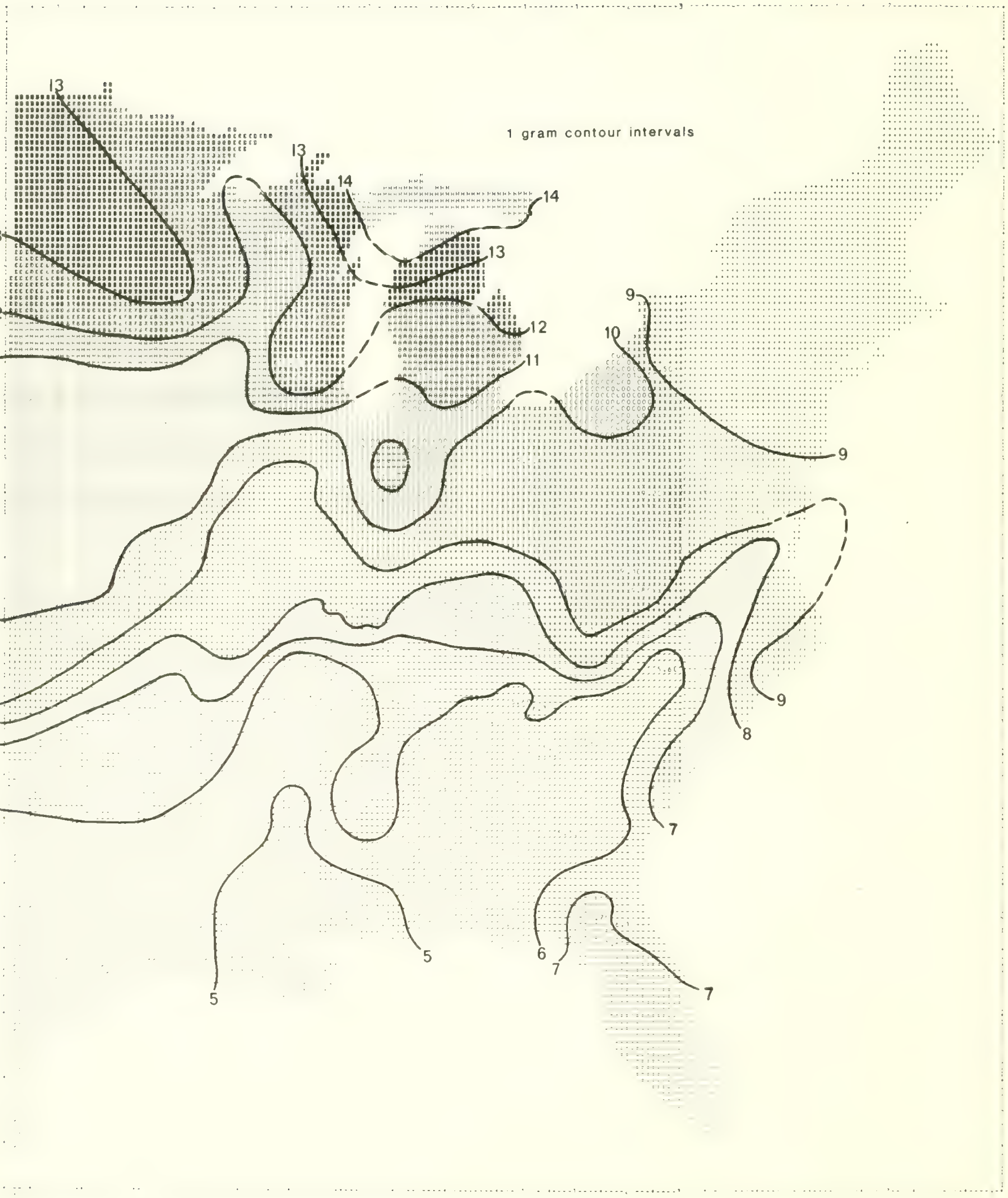

Figure 2.—*Black cherry mean seed weights (grams per 100 seeds)*

alies, the clinal trend in seed weight is strong and statistically significant (r = 0.78, df = 62).

The regression of seed weight on percent germination revealed a significant but negative correlation (r = −0.35, df = 80). In general, smaller seeds had better germination. Seed weight, however, had no significant effect on first year height growth in the nursery (r = 0.14, df = 80).

There appeared to be a strong relationship of increasing seed size with latitude. Not only were seeds larger, but the endocarps were thicker and harder to crack in the more northerly sources. The kernels were also larger in seeds from the north as compared to those from the southern part of the range. The ratio of endocarp weight to kernel weight increased with latitude (fig. 3). Nearly 55 percent of the oven-dry seed weight was contained in the endocarp, but this varied from 53.7 percent for southern sources to 59.3 percent for northern sources.

The 160 seedlots from the 1979 collections, for which data on oven-dry endocarp and kernel weights were obtained, were arbitrarily subdivided into three nearly equal groups based on latitude. The first group was designated the "Southern" and encompassed latitudes 19.7 to 34.5 degrees North, "Central" included latitudes 34.6 to 37.9 degrees North, "Northern" covered latitudes 38.0 to 45.6 degrees North. Mean values were calculated for each of the three groups as shown in Table 2.

Table 2.—*Endocarp and kernel weights for black cherry seeds grouped by latitude*

Group	Midpoint latitude	Endocarp (E)	Kernel (K)	Ratio E/K	n
		——gms/100 seeds——			
Southern	32.15	2.5881 a[1]	2.2330 a	1.1591	54
Central	36.25	2.9198 b	2.3531 a	1.2408	52
Northern	41.80	4.4056 c	3.0277 b	1.4551	54

[1] Mean values followed by the same letter are not significantly different when group means were tested against Student's *t*.

The Southern and Central groups showed greater variability in seed weights than the Northern group. These same groups also showed better germination when sown in the nursery, but the differences were not statistically significant when the endocarp-kernel ratio (E/K) was subjected to correlation analysis with germination (r = 0.24, df = 39).

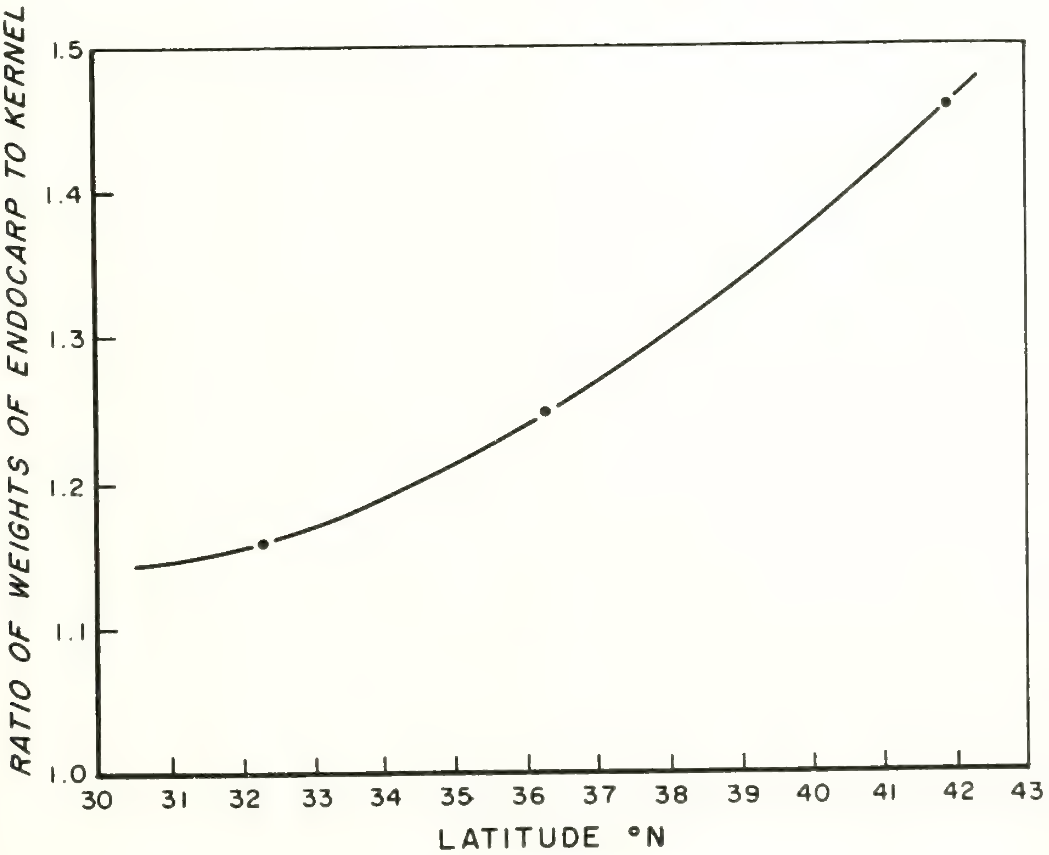

Figure 3.—*Relationship of endocarp to kernel weight of black cherry seed with latitude. Plots are means of Northern, Central, and Southern groups; each point is mean of >50 observations.*

Pearson correlation coefficients were computed for seed weights on 12 climatic variables and three geographic factors. These correlations confirmed the relationship between seed weight and latitude. As temperature and precipitation decreased, seed weight increased. Rainfall during the summer growing season had no significant effect on seed weight. In the 100-day period after the last spring frost, however, higher rainfall amounts were associated with greater seed weights. The correlation of seed weight with longitude was nonsignificant.

Seed weight was only weakly correlated with elevation. Sharik and Barnes (1979) found that patterns of variation associated with latitude cannot generally be strengthened by adjusting for elevational differences. They used a factor of 1.61°F per 1000 feet (0.3°C per 100 meters) of elevation in a study of native birches *(Betula* spp.) and ran comparisons of adjusted correlations on 47 morphological attributes. Most were less correlated when latitude was adjusted for elevation.

Germination

Percent germination was negatively correlated with latitude of seed origin (r = −0.19, df = 134). When the data were analyzed by latitudinal groups (table 3), the Northern group showed a highly significant correlation between percent germination and latitude of seed origin (r = −0.55, df = 35), whereas the correlations in the other two groups were non-significant. There were no differences in means between latitudinal groups. Thirty seedlots were stored for 1 year in a cold room at 3° to 5°C. When germination of these seedlots was compared between years, there was an overall increase. Not all seedlots benefited from storage; 22 showed increases, but in one instance, germination plummeted from 61 percent to zero in storage.

Height

Family mean heights at age 1 ranged from 32.7 cm (Tucker County, West Virginia) to 94.5 cm (Jones County, North Carolina) with a mean of 54.6 cm for the 82 families represented. Local seed collections from Oktibbeha County, Mississippi, averaged 54.2 cm slightly below the mean height. There were significant differences among family mean heights in the nursery (table 4).

According to Duncan's new multiple range test, six families were significantly taller than all the others represented in the study. Five of these six were not significantly different from one another, but the single family from Jones County, North Carolina, was significantly taller than all the other families in the test. Three families had significantly lower height growth in the first year.

Table 3.—*Germination percentage groups for 136 seedlots of stratified black cherry*

Percent germination	Number of Seedlots Northern	Central	Southern	Total
0.0	6	9	7	22
1 – 10	4	2	5	11
11 – 20	3	3	2	8
21 – 30	3	1	3	7
31 – 40	1	2	3	6
41 – 50	5	5	7	17
51 – 60	3	2	2	7
61 – 70	3	3	6	12
71 – 80	3	4	10	17
81 – 90	6	6	5	17
91 – 100	0	8	4	12
n =	37	45	54	136

[1] Germination after 35 days (1981).

Table 4.—*ANOVA for family mean heights of black cherry at the end of the first growing season*

Source	df	SS	MS	F
Families	81	47,927	591.7	6.92
Replications	5	14,351	2870.2	33.57
Error	405	34,624	85.5	
Total	491	96,902		

Mean height of each of the families was not correlated with seed weight (r = 0.10, df = 80). Neither was family mean height statistically correlated with latitude (r = 0.25, df = 80).

Family means were pooled for each of the seed sources represented. Correlations of source mean height on latitude were non-significant (r = −0.19, df = 33). Less than 4 percent of the variation in height growth can be explained by source differences in latitude.

Leaf Length and Width

Near the end of the growing season, in late October 1981, leaf samples were collected from each tree in the nursery test. The entire leaf nearest the point 15 cm below the terminal portion of bud of the seedling was picked from the tree. All the leaves from a single family were placed in a labeled zip-lock plastic bag. A total of 2,808 leaves were collected and measured to the nearest millimeter for length and width, an average of 34 leaves for each of the 82 families in the test.

When family mean leaf length-to-width ratios (l/w) were compared to family mean heights at age 1, the correlation coefficient was nonsignificant (r = −0.11, df = 80). The leaf 1/w, however, was effective in sepa-

Table 5.—*Comparison of leaf length, width, area, and height for 82 half-sib black cherry families grouped by latitude*

Group	Mean Leaf Length	Mean Leaf Width	Ratio of length to width	Mean leaf area	Mean ht	Corr. Coef. area vs. ht	n
	mm	*mm*		*mm²*	*cm*	*r*	
Northern	118.5	35.5	3.35	4211	48.94	.59	19
Central	108.1	37.2	2.92	3867	56.65	.26	31
Southern	99.0	38.2	2.59	3799	56.60	.69	32

rating black cherry into latitudinal groups (table 5). The l/w for southern, central, and northern groups were significantly different from one another. Longer and narrower leaves were found more frequently among northern sources.

Mean leaf length was multiplied by mean width to derive a relative leaf area for each family. The correlation for family mean leaf area on first year height was low but still significant ($r = 0.31$, $df = 80$). Families with larger leaves were generally taller. When the correlation was based on seed source means, relative leaf area accounted for about 34 percent of the variation in first year height ($r = 0.58$, $df = 33$). This correlation also held up well when families were grouped by latitude rather than by sources. As a group, the southern sources showed a strong and statistically significant correlation between leaf area and height, as did the northern sources. The central group was considerably more variable in the expression of this relationship, and the correlation was not significant. The wide differences between groups may possibly be due to the manner in which the groups were arranged by latitude, but more likely it is the result of evolutionary development and migration.

DISCUSSION

Of the 136 seedlots sown in the greenhouse, only 82 produced sufficient seedlings to establish nursery trials. These represented 35 geographic origins. Several seedlots showed no germination. Many of these originated in the northern collections. The abbreviated frost-free period at more northerly latitudes may only be sufficient for seed maturation. An after-ripening period may be necessary before germination can proceed, since seeds normally overwinter in the forest duff at these latitudes. In the more southerly latitudes, seed maturation is usually completed within the first half of the growing season and germination is therefore possible in the same year as seed fall. Whether germination actually occurs in the same year as seed fall has not been determined.

Damping-off was responsible for some losses in the trays sown in the greenhouse. One seedlot was decimated by this soil fungus. Other seedlots, collected from the same locality and placed in direct physical contact with the ravaged seedlot, suffered no losses to damping-off. Damage was usually confined to a particular seedlot in other instances as well, indicating that susceptibility to damping-off may be a variable that is under genetic control.

Since nursery seedling height was not related to seed weight, sizing of black cherry seeds would not appear to be beneficial. In bulked seedlots, it would lead to a serious reduction of the genetic base; this problem has been documented in conifers (Silen and Osterhaus 1979).

BLACK CHERRY SUBSPECIES/VARIETIES

It is possible that a few samples in this study might include *Prunus serotina* subsp. *hirsuta* (Ell.) McVaugh (1951). This subspecies is listed as *Prunus serotina* var. *alabamensis* (Mohr) Little in *Checklist of United States Trees* by E. L. Little, Jr. (1979). McVaugh's description of the subspecies *hirsuta* confines it to a relatively narrow sinuous band running from north-central Alabama north-eastward into Georgia, where it then plunges south for 200 km or more before turning generally eastward continuing into South Carolina. Samples 48, 49, 50, and 54 were taken within or very close to the range of *hirsuta*.

A scattered population with similar but not exactly typical characteristics of subsp. *hirsuta* is found in southeastern Alabama and adjacent portions of Georgia and Florida (McVaugh 1951). Sample points 58 and 59 were located within this area. Type collections made in 1900 were named *Prunus australis* Beadle. McVaugh tentatively includes this species type within subsp. *hirsuta* and Little considers *australis* to be within var. *alabamensis*.

McVaugh used the ratio of leaf length to width to describe differences in leaf morphology among the various subspecies of *Prunus serotina*. Foliage leaves, according to McVaugh, were mostly 4 cm wide by 9 cm long, a ratio of 2.25 for the general population. The mean l/w of the populations sampled in our study was 2.88 and family means ranged from 2.19 to 3.84. The subspecies *hirsuta* as described by McVaugh had l/w varying from about 1.5 to 2.75, the majority being less than 2.0. None of the families studied in this report had l/w less than 2.0, although three families originating from seed collections in Clarke County, Georgia, which lies well outside the present subsp. *hirsuta* range described by McVaugh, had some of the smallest l/w ratios. Mean seed weights were also lower in these families compared to sample weights from adjacent collection points. Cech and Kitzmiller (1968) felt that smaller seeds were probably associated with var. *alabamensis (i.e.,* subsp. *hirsuta)* in their study.

McVaugh postulated that subsp. *hirsuta* originated in the tropics of the New World and migrated as far north as the southern United States, and subsequently evolved into two geographically distinct populations (an eastern and western). Today, these widely separated populations retain remarkably similar morphological characteristics. To further support his hypothesis, McVaugh presented evidence that several species have undergone similar migrations and evolutionary development. In relatively recent geological times, *Prunus serotina* var. *serotina* evolved as an aggressive, pioneering tree species invading northward throughout the eastern United States and Canada. This ability to inhabit new areas would indicate that differences in seed size, seed weight, and seedling morphological characteristics could be anticipated. Indeed, our study shows that differences in seed weight and leaf size do exist, lending further support to McVaugh's hypothesis and contributing to a better understanding of the expressed racial variation evident in this wide-ranging forest tree species.

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Black cherry seeds, collected from 1 to 12 trees at 64 separate locations in the Eastern U.S., were analyzed for variations in weight, size, and endocarp and kernel weight in relation to latitude and climate. Seed characteristics varied clinally with latitude; those from farther north were larger in all respects.

Keywords: *Prunus serotina;* seed; provenance; cline; *P. serotina* subsp. *hirsuta; P. serotina* subsp. *australis; P. serotina* var. *alabamensis*

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Heavy Mortality and Succession in a Virgin Mixed Mesophytic Forest

Charles E. McGee

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SUMMARY

Recent mortality of large trees in a virgin mixed mesophytic forest provides insight into mortality patterns that might occur in wildernesses, parks, and other protected old-growth areas. During an 8-year period, 26 percent of the hickory *(Carya* spp.) and 18 percent of the white oak *(Quercus alba* L.) and northern red oak *(Q. rubra* L.) over 17 inches dbh have died in the 100-acre study area. The age of the dead trees ranged from 90 to 375 years. Dead northern red oak averaged 135 years old while white oak, chestnut oak *(Q. prinus* L.), and hickory averaged about 210 years old. Cause of the sudden mortality is uncertain but appears to be a combination of senescence, drought, insect attack, and blowdown. Anticipated successional changes include a marked increase in sugar maple *(Acer saccharum* Marsh.) in the overstory at the expense of the oaks, particularly northern red. Meanwhile, the hickories may lose importance but will maintain a significant position in the overstory, along with yellow-poplar.

Heavy Mortality and Succession in a Virgin Mixed Mesophytic Forest

Charles E. McGee

INTRODUCTION

Millions of acres of forest land are being set aside as natural areas, parks, or wildernesses. Little is known about how these vast forests will change with time. However, one often hears laymen speak of setting aside certain forested areas so that they may be preserved in their present state in perpetuity. While foresters and ecologists know that preserved areas will undergo continual change, they have generally assumed that changes in old-growth forests would be gradual and subtle. Observations in Dick Cove Natural Area, a virgin, old-growth forest, suggest that changes in forest composition, structure, and appearance may not be either gradual or subtle. Recent substantial mortality among the larger hickories and oaks is changing species composition, stand structure, and aesthetic values. Many researchers have discussed patterns of disturbance and the live vegetation of upland hardwoods, but few have had the opportunity to study mortality in very old undisturbed forests (Lorimer 1980, Muller 1982, Runkle 1981, Runkle 1982). Romme and Martin (1983) have examined tree-fall gap dynamics and relate tree fall to frequency of gaps, season of tree fall, and canopy turn-over time. The purpose of this paper is to identify the species and age of recent mortality, to describe changes in the stand, and to relate mortality to the living stand. Hopefully, this information on mortality and species longevity will help forest managers and planners anticipate what might happen on other protected old-growth forests.

THE STUDY AREA

Dick Cove Natural Area is a mixed mesophytic forest growing on the western slope of the Cumberland Plateau in Franklin County, Tennessee (fig. 1). The 100-acre, old-growth, uncut forest is the property of the University of the South and has been nominated for the National Registry for Natural Landmarks and for the Tennessee Natural Area Registry. There is no evidence or record of any cutting on the area. There is a possibility that a few trees may have been cut prior to 1900. However, any logging or cutting that occurred would have been very limited in scope.

The study area is bisected by an intermittent north-south stream. Several other streams feed into the main stream or disappear into sinkholes. The area is characterized by two main landtypes. These landtypes have been identified and described by Smalley (1982). The upper sandstone slopes and benches occur just below the Plateau escarpment and are characterized by a northerly aspect and deep to very deep well-drained loamy soils formed from sandstone, siltstone, and shale (Landtype 16). Much of the surface is covered with sandstone boulders. Site index at age 50 for this landtype, as estimated by Smalley, is 100 for yellow-poplar, 90 for black cherry, white ash, and black walnut, 80 for northern red oak, and 75 for white oak. Scientific names are given in table 9. About 60 percent of Dick Cove is in this landtype.

The lower limestone slopes, benches, and spur ridges are characterized by moderately deep to very deep, well-drained, loamy and clayey soils formed in

Figure 1.—*Dick Cove study area viewed from a Cumberland Plateau bluff.*

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limestone residuum and some colluvium from sandstone, siltstone, and shale (Landtype 18). Estimated site index at age 50 for this type is 85 for yellow-poplar, 70 for white and red oaks, and 60 for southern red oak. About 30 percent of the area is in this landtype. The remaining 10 percent of the area is mostly on south-facing slopes and falls in other landtypes.

The study area matches the description of a mixed mesophytic forest (Braun 1950). The overstory includes all the species listed by Braun, and the topographical layout of the area is very similar to and within 2 miles of an area described by Braun as typical for cliff sections of the Cumberland Plateau escarpment. Sawtimber volume averages more than 14,000 fbm per acre across the 100-acre area.

METHODS

In the spring of 1982, a general cruise of the study area identified the species and diameters of all living trees 5.0 inches dbh or larger. In a separate cruise, every tree in the area over 9.0 inches dbh that appeared to have been dead 8 years or less was examined. The following data were recorded for dead trees that were judged to have been dominant or codominant:

1. Species
2. Diameter (breast height)
3. Total height (estimated)
4. Date of mortality (years dead)
5. Cause of mortality (blowdown, insects, drought, unknown, etc.)
6. Basal area of surrounding trees (prism count)
7. Age (visual estimate—no boring or cutting at this time—ring counts were made later)
8. Condition of tree (standing, broken, down, etc.)

For dead trees that had not been dominant or codominant, only species and diameter were recorded.

These mortality surveys identified 446 dead dominants or codominants and 241 dead trees that were not dominant or codominant. Accurate ring counts were taken on 186 of the 446 dead dominants and codominants by increment boring or cutting a section at the base of a down tree. Many additional borings and cuttings were attempted, but due to rotten bole centers and other reasons, the ages were not considered accurate and are not included. Diameter growth for 10 and 20 years prior to mortality was also measured.

The time of mortality was estimated by the sampling crew using a set of criteria developed from the condition of a sample of nearby dead trees that had been dead for known periods of time. It is likely that there is substantial error in the estimates of time of death for trees dead more than 3 or 4 years. However, most of the mortality has occurred within the last 3 years, so estimates of time of death are considered reliable.

Rainfall and temperature measurements referred to later were recorded at a weather station 3 miles from Dick Cove.

RESULTS

The Living Stand

In June 1982, the study area contained 7,777 live trees 5.0 inches dbh or larger (table 1). The stand thus contains about 78 trees per acre, of which 25 are in the 18-inch dbh or larger size class, 32 are 10 to 16 inches dbh, and 21 are 6 to 8 inches dbh. About 25 percent of all live trees in the larger size class are northern red oak, making it the principal species in this class. The remaining 75 percent of the trees in the 18-inch dbh class and larger includes shagbark hickory, bitternut hickory, pignut hickory, chestnut oak, white oak, yellow-poplar, sugar maple, and 11 other species. Sugar maple and the hickories are the most important trees in the 10- to 16-inch dbh class, making up 40 percent of the stems in this class. Twenty-six species make up the remaining 60 percent of the trees in this category. Sugar maple is the most numerous tree in the 6- to 8-inch dbh category, accounting for one-third of all stems in this group. The scarcity of northern red oak, white oak, and greatly reduced numbers of chestnut oak in the smaller size classes, suggests that the future oak component of this stand will be altered substantially. Based on current stand tables, it appears that the shift in species will heavily favor sugar maple, with the number of dominant hickories and yellow-poplar also increasing.

Many of the living trees in the 18-inch dbh and larger size classes are not vigorous; several hundred are likely to die soon.

Current Mortality

The surveys in 1982 found 687 dead trees that were larger than 9.0 inches dbh; 446 of these had been dominant or codominant and 241 were intermediate (tables 2 and 3). Northern red oak, shagbark hickory, bitternut hickory, white oak, and chestnut oak made up most of the mortality in dominant trees (fig. 2). These species plus black locust also include most of the mortality among the intermediates. The distribution of mortality by size class is surprising. One would generally expect mortality at any given time in an undisturbed stand to be greater among smaller trees. While distribution of the living stand generally fits the reverse J-shape curve that might be expected in old, undisturbed stands, the distribution of mortality is weighted heavily in favor of the larger trees. It is relevant that at the time of the survey 547 of the 687 dead trees were standing.

Table 1.—*Living trees in 100-acre Dick Cove study area as of June 1982, by species and diameter class*

Diameter class	Species[2]											Relative density
	NRO	WO	CO	BO	WA	SM	YP	HIC	BaW	Others[3]	Total	
	number											
6	15	49	97	....	38	372	113	127	48	195	1054	13.6
8	39	46	109	....	47	362	79	149	41	165	1037	13.3
10	45	43	96	3	40	257	72	146	33	102	837	10.8
12	86	57	114	9	38	225	57	218	31	127	962	12.4
14	88	55	92	6	34	158	45	153	29	118	778	10.0
16	84	59	96	8	26	81	43	149	25	83	654	8.4
18	134	51	73	8	30	85	46	106	25	83	641	8.2
20	125	30	63	4	30	54	30	109	30	69	544	7.0
22	114	37	50	3	19	25	31	63	17	41	400	5.2
24	81	28	27	1	14	13	29	40	16	34	283	3.6
26	62	27	16	....	7	6	18	17	4	16	173	2.2
28	42	15	12	1	8	7	23	16	8	7	139	1.8
30	25	14	14	....	7	3	10	12	3	15	103	1.3
32	19	16	12	1	3	2	8	9	2	7	79	1.0
34	5	6	9	....	3	....	9	1	2	2	37	0.5
36	7	8	4	....	2	....	6	1	1	4	33	0.4
38	2	2	3	....	....	....	1	1	....	....	9	0.1
40 +	3	4	3	....	....	....	2	....	....	2	14	0.2
Total	976	547	890	44	346	1650	622	1317	315	1070	7777	
Relative Density	12.6	7.0	11.4	0.6	4.4	21.2	8.0	16.9	4.1	13.8		

[1] Diameters (dbh) are in 2-inch classes; 6-inch diameter includes 5.0 to 6.9 inches, etc.

[2] Species identification and scientific names are given in table 9.

[3] Others includes blackgum, buckeye, cucumber, chinkapin oak, black walnut, black cherry, black locust, redbud, sassafras, red maple, dogwood, sourwood, ironwood, beech, persimmon, and yellowwood.

Table 2.—*Tree mortality by species and crown class*

Crown class	Species[1]																	
	NRO	WO	CO	Other HIC	SB HIC	BG	CU	YP	ELM	BW	BYE	BaW	WA	BL	SM	BO	CPO	Total
	Number																	
Dominant and codominant trees	141	52	27	101	52	8	1	5	19	3	6	9	6	7	5	1	3	446
Other trees	46	15	15	90	....	1	1	2	....	6	12	6	8	32	6	...	1	241
Total dead trees	187	67	42	191	52	9	2	7	19	9	18	15	14	39	11	1	4	687

[1] Species identification and scientific names are given in table 9.

Mortality in Relation to the Living Stand

The total population of trees 9 inches dbh and larger on the 100-acre study area is 6,373. Of these, 10.8 percent are dead (table 4). Since the mortality has occurred during the past 8 years, the loss of 10.8 percent of the stand, while high, might not be a cause of concern. However, when mortality is studied by species and size class, and when it is noted that most mortality occurred in the last 3 years (table 5), the developments in this stand become of considerable interest.

Fifteen percent of the trees 18 inches dbh or larger and 23 percent of those 30 inches or larger have died. These values far exceed the 6 percent overstory mortality suggested by Lorimer (1980) as a long-range 10-year mortality average under steady state conditions. In the 18-inch or larger class, 26 percent of the hickory, 19 percent of the white oak, and 17 percent of the northern red oak have died. On the other hand, only 2 to 5 percent of the sugar maple, yellow-poplar, and white ash larger than 18 inches dbh have died. Such heavy selective mortality among the dominant and codominant trees will change the composition and structure of the future stand.

Only 7.3 percent of the trees in the 10- to 16-inch dbh size class have died. However, over half of the dead trees in this size class are hickory or northern red oak.

Table [illegible]

Dbh	[illegible]	Other	Total [illegible]
[illegible]			
9	...	5	5
10		11	11
11		29	29
12	1	[illegible]	50
13	2	21	23
14	3	17	20
15	4	33	37
16	12	31	43
17	17	[illegible]	[illegible]
18	[illegible]	12	34
19	30	6	36
20	29	3	32
21	24	1	[illegible]
22	35	1	36
23	33	4	37
24	39	—	39
25	29	—	29
26	32	—	[illegible]
27	26	—	26
28	15	—	15
29	13	—	13
30	10	—	10
31	[illegible]	....	[illegible]
32	10	—	10
33	[illegible]		[illegible]
34	19	...	19
35	9		9
36	9		9
37	4	....	4
38	2		2
39	1	....	1
40	2		2
42	2		2
Total	[illegible]	[illegible]	[illegible]

Other includes mostly intermediate trees not classed as dominant or codominant.

Mortality by Tree Age

Relatively accurate age counts were available from 186 of the 446 dominant and codominant dead trees (table 5) (fig. 3). Average ages of the dead trees varied substantially by species. Northern red oak died at a much younger age than the other species. The age of northern red oak at mortality ranged from 80 to 240 years and averaged 135. The average age at the time of mortality was fairly uniform for the other species, ranging from 172 years for white ash to 210 for chestnut oak. The oldest dead tree is a hickory: 375 years old. While northern red oak died younger than some other species, it can grow quite large, as the largest diameter dead tree is a 42-inch northern red oak (table 6).

Mortality and Stand Density

The average basal area for the entire study area is about 100 square feet per acre. According to prism counts, the basal area around 186 of the dead dominant or codominant trees also averaged 100 square feet per acre, but ranged from 40 to 170 square feet per acre. It was concluded that there was no obvious linkage between stand density and mortality of the larger trees (table 5).

Mortality and Radial Growth

Radial growth measurements on 161 of the dead trees suggest that growth rates may have been decreasing prior to mortality (table 7) (fig. 3). Average radial growth on 66 northern red oak was substantially less in the final 10 years than in the preceding 10 years (based on a t-test, growth differences exceeded the level needed to reject the null hypothesis that there were no differences). Growth rates of white oak and hickory were only slightly reduced in the period just prior to mortality.

Causes of Mortality

The actual cause of mortality for any specific tree in this study is open to question. However, the possible effect of age, climate, defoliation by insects, and blowdown merit comment. The concentration of mortality observed in Dick Cove might be the result of interaction of these causes, any one of which, operating singly, probably would not have caused widespread mortality.

Age must be considered a possible cause of mortality. While the upper limit of tree species longevity is not well documented, many of the older dead trees in this stand are well beyond the average ages normally encountered. As trees approach large sizes with increased amounts of dead wood, it is likely that they become more susceptible to damaging agents that earlier in the tree's life would have caused only a loss

Figure [illegible] occurring in Dick Cove.

Table 4.—*Tree mortality in relation to total population by dbh size class*

Species[1]	Live trees 18 inches dbh[2]	Dead treees 18 inches dbh[2]	Mortality 18 inches dbh[2]	Live trees 10 – 16 inches dbh[3]	Dead trees 10 – 16 inches dbh[3]	Mortality 10 – 16 inches dbh[3]	Total population	Total mortality
	number		*percent*	*number*		*percent*	*number*	*percent*
NRO	619	130	17.4	303	57	15.8	1109	16.9
WO	238	55	18.8	214	12	5.3	519	12.9
CO	286	30	9.5	398	12	2.9	726	5.8
BO	18	1	5.3	26	.....	.....	45	2.2
WA	123	6	4.6	138	8	5.5	275	5.1
SM	195	4	2.0	721	7	1.0	927	1.2
YP	213	6	2.7	217	1	0.5	437	1.6
HIC	375	135	26.5	666	108	14.0	1284	18.9
Other	388	66	14.5	548	49	8.2	1051	10.9
Total	2455	433		3231	254		6373	
Average			15.0			7.3		10.8

[1] Species identification and scientific names are given in table 9.

[2] 18 inch size class includes trees 17.0 inches dbh and greater.

[3] 10 – 16 inch size class includes 9.0 – 16.9 inches dbh.

Table 5.—*Dominant and codominant tree mortality by species, size, age, and stand density*[1]

Species	Dead trees	Age		Dbh		Basal area		Years dead average
		Range	Average	Range	Average	Range	Average	
	number	*years*		*inches*		*square feet*		*number*
Northern red oak	68	80 – 210	135	19 – 42	28	60 – 140	98	2
Chinkapin oak	2	150 – 200	175	16 – 24	20	70 – 90	80	3
White oak	24	150 – 320	205	18 – 38	26	70 – 120	100	3
Chestnut oak	17	125 – 340	210	18 – 35	29	70 – 140	96	2
Hickories	53	100 – 375	208	12 – 36	22	40 – 170	98	2
Shagbark hickory	20	110 – 275	188	13 – 30	21	50 – 140	100	2
White ash	2	155 – 190	172	19 – 24	22	100 – 120	110	2

[1] This table includes only those trees for which ages could be accurately determined.

Table 6.—*Largest dead trees by species*[1]

Species	Dbh
	inches
Northern red oak	42
Chestnut oak	40
Hickories	40
Basswood	39
White oak	38
Shagbark hickory	37
Yellow-poplar	35
Yellow buckeye	34
Elm	34
White ash	34
Chinkapin oak	30
Blackgum	28
Cucumbertree	28
Sugar maple	26
Black locust	25
Black walnut	22
Black oak	21

[1] Diameters shown here may differ from diameter ranges in table 5. Table 5 provides diameter ranges only for those trees that could be aged accurately.

Table 7.—*Radial growth of trees, 20 years prior to mortality*

Species	Dead trees	Growth by 10-year periods	
		Final	Preceding
	number	*inches/tree*	
Northern red oak	66	0.62	0.79
White oak	23	0.48	0.54
Hickory	72	0.37	0.44

in growth. However, since the range in ages of dead trees is quite broad, age is not likely the only cause of mortality.

Weather conditions over the past decade are also likely causes of mortality. Rainfall in 3 out of the 4 years preceding the mortality survey had been below average (table 8). In particular, 1978 was a very stressful year for all vegetation in the area and was extremely damaging to trees. Total rainfall was 18 inches below the 61-inch, 25-year average. Only 12 inches, or about half the long-term average, fell from June through October, and no rain fell from August 17 to September 14. This drought, coupled with temperatures 1° to 3° F above normal, created a stressful period that could cause mortality.

Defoliating insects attacked oaks, hickories, and other hardwoods at nearly epidemic proportions in 1979 and 1980 in the vicinity of the study area. However, the intensity of the insect attack in Dick Cove was not monitored. It is the general opinion of workers in the area that many trees in Dick Cove were infested with the insects and their presence could have contributed to mortality. Insects known to have been active in the area included: the spring cankerworm *(Paleacrita vernata* (Peck)), linden looper *(Erannis tiliaria* Harr.), and the half-winged geometer *(Phigalia titea* Cram.).

Blowdown also caused some mortality. Approximately 75 live trees were uprooted and 65 dead trees fell over during the last 8 years. Some workers (Romme and Martin 1983) suggest that blowdown is a major cause of mortality in old-growth forests. In this case, blowdown is an important factor but is certainly not the prime cause of mortality.

Table 8.—*Precipitation near Dick Cove 1972 – 1981*

Year	Precipitation				
	Mar. – May	June – Aug.	Sept. – Oct.	Growing season (Mar. – Aug.)	Total
	inches				
1972	18	16	14	34	75
1973	23	15	9	38	79
1974	18	14	5	32	71
1975	25	14	23	39	83
1976	14	12	11	26	51
1977	23	12	16	35	76
1978	13	9	3	22	43
1979	23	15	11	38	70
1980	22	10	7	32	54
1981	12	13	8	25	48
24-Year Avg.	18	14	9	33	61

DISCUSSION

Mortality in upland hardwood forests is a normal occurrence. Many thousands of seedlings germinate that never live to become saplings. Likewise, numerous saplings and pole-sized trees are crowded out and die. Large established trees will also die, but their death has been assumed to be of an occasional nature and dispersed over time and space (Runkle 1981, 1982). Thus, it is noteworthy when substantial mortality occurs in large trees within a relatively brief time span in an undisturbed upland forest.

Eleven percent of all the overstory trees on the Dick Cove area died during the past 8 years, but most

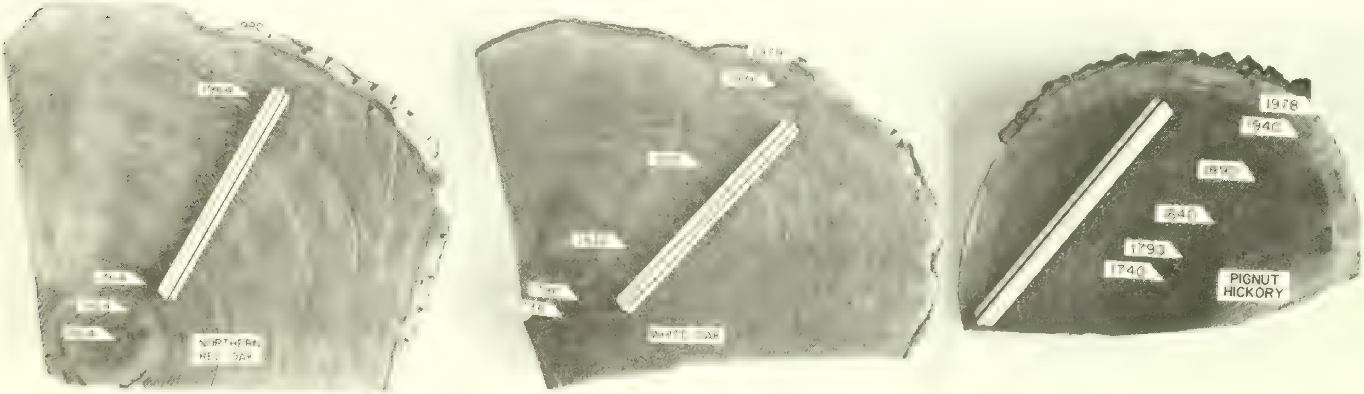

Figure 3.—*Sections of a 166-year-old northern red oak, a 243-year-old white oak and a 238-year-old pignut hickory.*

of the dominant and codominant trees had been dead less than 3 years (table 5). Whether this concentrated mortality is a normal occurrence that can be anticipated in old-growth forests or was triggered by a unique combination of factors is not known. However, it is a safe speculation that as trees age they tend to become more likely to be killed by antagonistic factors. Thus, as large groups of trees increase in size and age, it is likely that they will be increasingly subject to heavy mortality when stress occurs.

Stand structure of the living trees in this study fits a J-shaped curve that is usually anticipated in all-aged, unmanaged forests (fig. 4). Large numbers of trees are present in the smaller diameter classes and their numbers decrease exponentially as diameters increase. However, the distribution of mortality does not fit the curve for the living stand. Relatively few of the 9-, 10-, and 11-inch trees have died, creating a somewhat bell-shaped curve for mortality. However, numbers alone do not describe what is happening to the stand.

The species composition and stand structure of the surviving stand indicate that the entire stand is undergoing a substantial change. The current mortality appears to be accelerating a change from a predominantly oak and hickory forest to one heavily populated with sugar maple and yellow-poplar. The predominant species in the overstory has been northern red oak. However, 17 percent mortality of overstory trees coupled with relatively few replacement trees in the smaller size classes suggests that northern red oak will not be predominant much longer.

The hickory group (shagbark, pignut, and bitternut) has been a major group in the overstory, second only to northern red oak in importance. Even with 27 percent mortality in large hickory trees, the presence of many smaller overstory trees and numerous pole-sized trees suggests that the hickory group will continue for some time as an important group. Chestnut oak has had about 10 percent mortality in the overstory, but with the substantial number of smaller overstory trees and poles it can increase in importance as an overstory tree. White oak, with 19 percent mortality in large overstory trees and relatively fewer small overstory trees and poles, will lose importance in the years to come. Yellow-poplar has broad distri-

Table 9.—*Scientific names and abbreviations*

Common names	Scientific names	Table abbreviation
Ash, white	*Fraxinus americana* L.	WA
Basswood, white	*Tilia heterophylla* Vent.	BaW
Beech	*Fagus grandifolia* Ehrh.	
Blackgum	*Nyssa sylvatica* Marsh.	BG
Buckeye	*Aesculus octandra* Marsh.	BYE
Cherry, black	*Prunus serotina* Ehrh.	
Cumcumbertree	*Magnolia acuminata* L.	CU
Dogwood	*Cornus florida* L.	
Elm	*Ulmus americana* L.	ELM
Hickory	*Carya* spp.	HIC
Bitternut	*C. cordiformis* (Wangenh.) K. Koch	
Pignut	*C. glabra* (Mill.) Sweet	
Shagbark	*C. ovata* (Mill.) K. Koch	SB HIC
Ironwood	*Ostrya virginiana* (Mill.) K. Koch	
Locust, black	*Robinia pseudoacacia* L.	BL
Maple	*Acer* spp.	
Red	*A. rubrum* L.	
Sugar	*A. saccharum* Marsh.	SM
Oak	*Quercus* spp.	
Black	*Q. velutina* Lam.	BO
Chestnut	*Q. prinus* L.	CO
Chinkapin	*Q. muehlenbergii* Engelm.	CPO
Northern red	*Q. rubra* L.	NRO
Southern red	*Q. falcata* Michx.	
White	*Q. alba* L.	WO
Persimmon	*Diospyros virginiana* L.	
Redbud	*Cercis canadensis* L.	
Sassafras	*Sassafras albidum* (Nutt.) Nees	
Sourwood	*Oxydendrum arboreum* (L) DC	
Walnut, black	*Juglans nigra* L.	BW
Yellow-poplar	*Liriodendron tulipifera* L.	YP
Yellowwood	*Cladrastis kentukea* (Dum.-Cours.) Rudd	

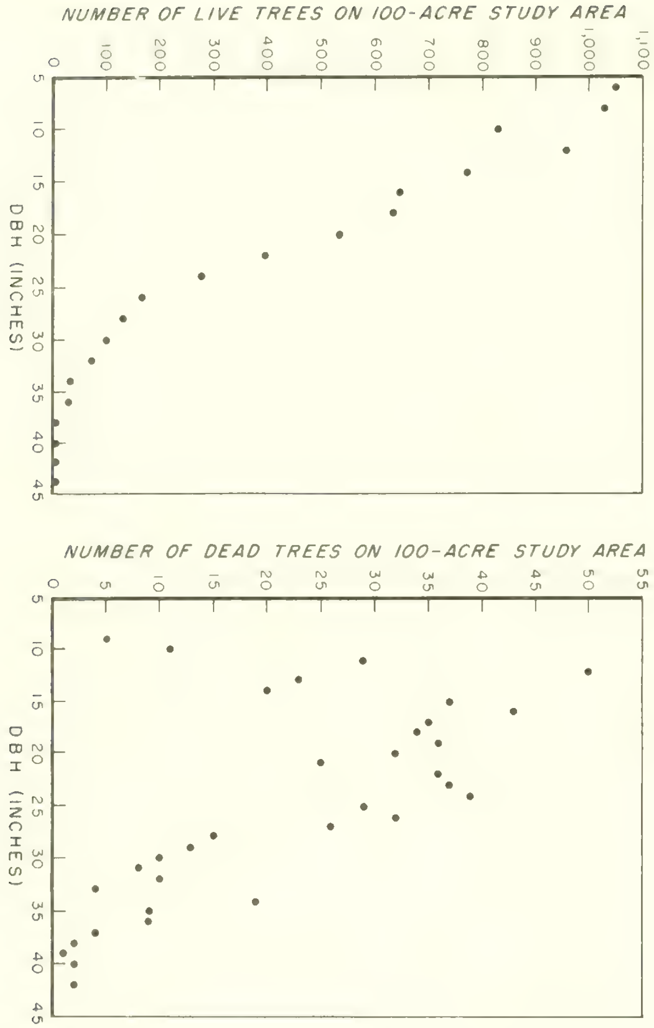

Figure 4.—*Distribution of living trees (A) and dead trees (B) by diameter class.*

bution in all size classes. Very limited mortality plus similar numbers of trees in large overstory, small overstory, and pole-sized trees suggests that yellow-poplar will at least maintain its current stand position and could improve substantially. Sugar maple will probably be the most important species in the future. Insignificant mortality of sugar maple in the large overstory and its predominance among the potential replacement trees in the smaller size classes suggest that sugar maple will replace northern red oak as the predominant species. Among the species grouped in the "other" category, elm merits special mention. Over 63 percent of the relatively small number of large elm in the overstory have died. However, there are enough smaller elms to at least maintain a position in the stand.

Perhaps the most interesting observation relative to the changes in species importance is that two species that appear to have an important future in the stand are ecologically different. Sugar maple, a shade-tolerant and slow-growing tree, is quite a contrast to yellow-poplar, an intolerant but fast-growing tree. It is quite likely that while the two species are growing in the same general area, they regenerated under different conditions.

The age of the dominant and codominant trees that have died may provide considerable insight as to how other old stands may react to stress in the future. The relatively young age at which the northern red oak mortality begins, plus the species' apparent inability to establish itself in the understory, suggests that the species may become a limited occupant of mixed mesophytic old-growth forests. The oldest dead tree in the study was a 375-year-old hickory. However, many younger hickories also died. In view of the wide range of ages at which mortality occurs, it can be reasonably assumed that all of the mortality was not related to physiological senescence.

The most important question about the widespread mortality in Dick Cove is: why has the mortality occurred? Unfortunately, there is no way to determine with certainty why any one of the 687 trees died except for those few that were blown over. It is almost a certainty that old age, the summer drought in 1978, above-average temperatures, and defoliating insects contributed to the death of the trees. One might assume that this particular stand enjoyed very good growing conditions during previous decades, thus allowing trees that might have died in earlier stress periods to continue to live and grow very large. Thus, when a combination of stress-causing forces did finally occur, many trees died at about the same time.

The frequency of such a pattern should be of considerable interest to managers of parks and wildernesses where trees will be allowed to develop and undergo mortality independent of man's actions.

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Age and species of tree mortality in an old growth hardwood forest are presented, with speculation on the cause of mortality and long range successional changes.

Keywords: *Quercus* spp., old growth, senescence, selective mortality, mortality ages.

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Common Herbaceous Plants of Southern Forest Range

Harold E. Grelen and Ralph H. Hughes

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ACKNOWLEDGEMENT

As this handbook is essentially a revision of the Forest Service Research Paper SO-23, "Common plants of longleaf pine-bluestem ranges," (Grelen and Duvall 1966) and much of that information is repeated here, the authors are indebted to Vinson L. Duvall, U.S. Forest Service, retired, and to all those who helped with the previous book. About a dozen Federal and State biologists and ecologists from selected areas of the South assisted in expanding the list of plants to be included in this book.

A. W. (Al) Johnson, now retired from the U.S. Forest Service, assisted with the earlier book and provided numerous plant collections and photographs for use by the illustrator in this revision. Bryan A. Jowers, of the Louisiana College Department of Art, drew all illustrations of plants added in this revision. Drs. Charles M. Allen and R. Dale Thomas, plant taxonomists at Louisiana State University at Eunice and Northeast Louisiana University, respectively, reviewed the manuscript and made valuable suggestions regarding plant uses, common names, and closely related species.

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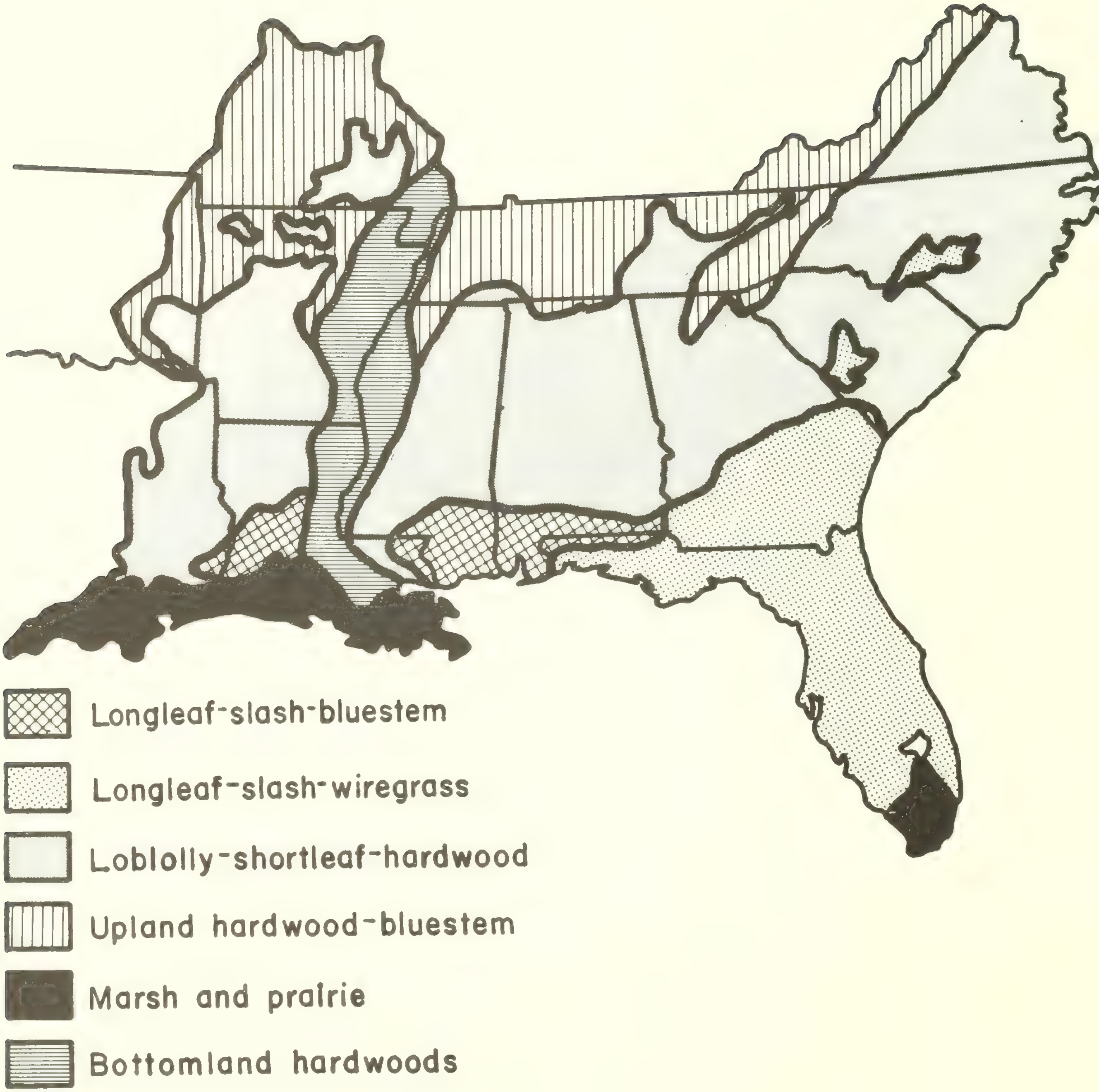

Range Types of the South.

Common Herbaceous Plants of Southern Forest Range

Harold E. Grelen and Ralph H. Hughes

INTRODUCTION

This handbook describes and illustrates selected grasses, grasslike plants, and forbs found on pine or pine-hardwood sites from east Texas to Virginia. Some, like little bluestem, *Schizachyrium scoparium*, are valuable forage plants Southwide. Others, such as Nuttall wildindigo, *Baptisia nuttalliana*, are worthless weeds.

An earlier publication, "Common Plants of Longleaf Pine-Bluestem Range," (Grelen and Duvall 1966), dealt with plants common to the longleaf-slash pine-bluestem range type from east Texas to south Alabama and the northern part of the Florida panhandle. In addition to the herbaceous plants from the previous publication, this book includes plants from the longleaf-slash pine-wiregrass type of Florida, south Georgia, and the Carolinas and the southwide loblolly-shortleaf pine-hardwood type (see map). Many plants are found in all three types. Range types coincide with timber types (USDA 1969) except that the longleaf-slash pine forest type is divided into the longleaf-slash pine-bluestem and the longleaf-slash pine-wiregrass range types. Resources of the range types included in this publication, as well as others indicated on the type maps, are discussed in "Range Resources of the South" (Southern Section SRM 1974). Woody plants were omitted from this revision because there are now several books illustrating and describing southern trees, shrubs, and woody vines, including the wildlife food values of such plants (Dean 1968, Halls 1977, Halls and Ripley 1961, Oefinger and Halls 1974).

Plants are described in general terms with clues for identification and separation from a closely related plant or one with similar appearance, where appropriate. Forage value for livestock and wildlife, a technical description, and geographic range are also given.

Plant nomenclature generally follows that of the "National List of Scientific Plant Names" (USDA 1982). Common names were gleaned from checklists or other publications (Wolff 1954; Gould 1969; Hilmon 1964; Leithead, Yarlett, and Shiflet 1971). "Standardized Plant Names" (Kelsey and Dayton 1942) was also consulted, and at least one name was coined by the authors.

Scientific names following the title of each plant description are those indicated as preferred in the "National List of Scientific Plant Names." Names in parenthesis following the preferred name may be more familiar and most are valid synonyms. Preferred scientific names elsewhere in the text may be followed by a synonym in parenthesis.

Metric measurements are used in the technical section of each species description and in the illustrations. In the general section, intended for the nonbotanist, English measurements are used. The habit silhouettes show both metric and English scales.

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GRASSES

The native grasses of the South vary widely in size, habit, environmental adaptability, and usefulness. Except for the woody bamboos, all species are annual or perennial herbs. Height varies from a few inches to 25 feet. Bunch grasses predominate, but many grasses creep by rhizomes or stolons. Despite these variations, many vegetative characters are relatively constant for all grasses. Stems are typically hollow, though occasionally solid, with prominent joints or nodes. Leaves, arising alternately from the nodes in two ranks, are elongate; although some are not much more than 1 inch long, width is never more than one-third the length. Leaf margins and veins are approximately parallel. The part of the leaf that clasps the stem is the **sheath**, and in most grasses the edges are not fused and the sheath is said to be open. The upper or free portion of the leaf is called the **blade**. The juncture of the sheath and blade on the outer surface is termed the **collar**. Many grasses have a **ligule** (a membranous scale or fringe of hairs) at this juncture on the inner surface. Although these features are usually enough to distinguish grasses from other plants, it is sometimes difficult to differentiate between plants of the grass family, Gramineae, and the closely related sedge and rush families, Cyperaceae and Juncaceae.

Hitchcock (1950) numbered the grasses in the United States, excluding Alaska and Hawaii, at 185 genera and 1,518 species. Fernald (1950) indicated 110 genera with 487 species for the central and northeastern regions of the U.S. Louisiana has 99 genera and 328 species (Allen 1980). Ward (1968) lists 101 genera and 423 species for Florida. Thus, approximately half of the grass genera found in the nation are represented in the South.

Bluestems—*Andropogon* spp., *Schizachyrium* spp., and *Bothriochloa* spp.

The bluestems, known also as "beardgrasses" or "sagegrasses," are the most valuable native forage grasses in the South. They usually furnish more than half the forage for range cattle. All bluestems were included in the single genus *Andropogon* by Hitchcock (1950), although he divided his generic key into sections corresponding to genera of earlier authors. Gould (1967) revised the genus *Andropogon*, recognizing as genera the subgenera *Schizachyrium* and *Bothriochloa* as well as *Andropogon*. Several recent taxonomic manuals (Correll and Johnston 1970, Godfrey and Wooten 1979, Allen 1980) and the "National List of Scientific Plant Names" (USDA 1982) have adopted Gould's revision.

No species of *Bothriochloa* was considered common enough in the South to be included in this book. Silver bluestem, *Bothriochloa saccharoides* (Swartz) Rydb., is found occasionally in Louisiana and as far east as Alabama.

Southern bluestems are mainly bunch grasses. Heights range from about 1 foot in fineleaf bluestem to more than 6 feet in big bluestem. Little bluestem and slender bluestem are the main forage species on most longleaf pine-bluestem sites, and creeping bluestem is important on longleaf pine-wiregrass sites of Florida and Georgia. Bushy bluestem often forms extensive stands on soils too wet for upland species.

Most species do not flower until late summer or fall; hence, identification during much of the year must be from vegetative characters. Culms are solid, while those of most grasses are hollow. Tufts generally spread by tillering, but a few species, e.g., pinehill bluestem and big bluestem, may be rhizomatous.

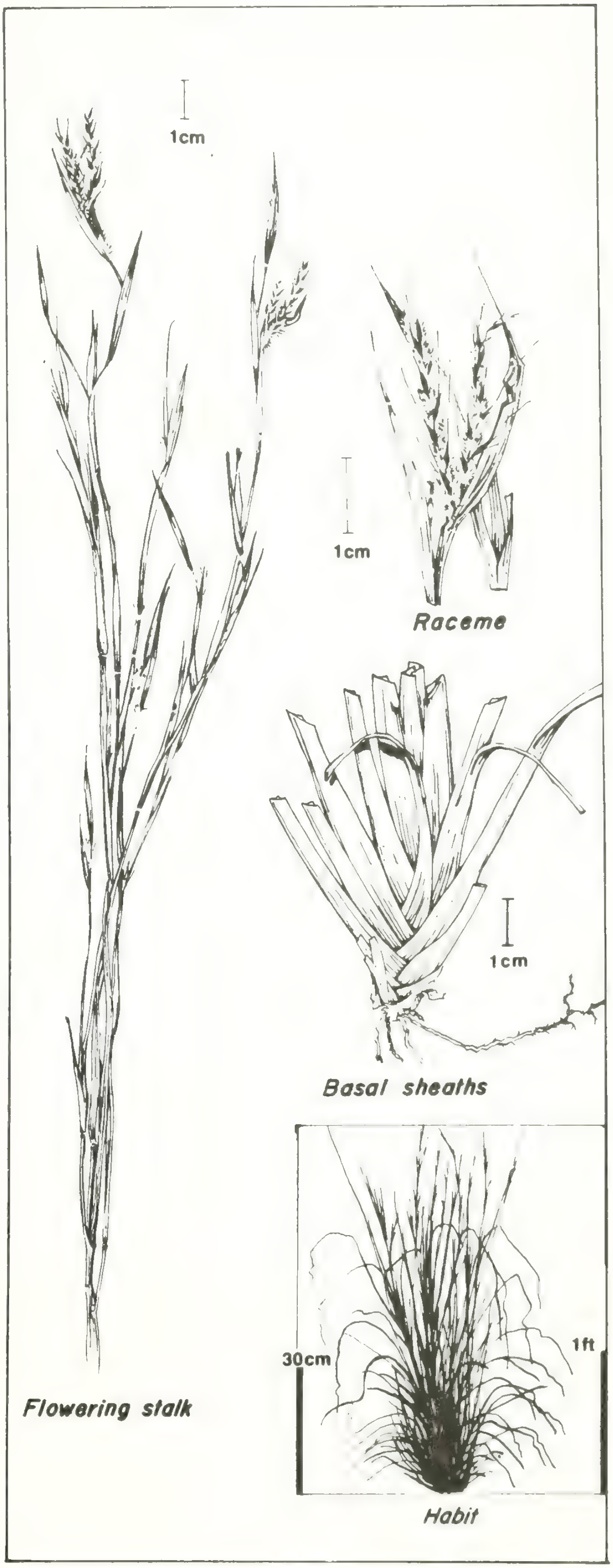
Inflorescences consist of several to many hairy racemes (spikelike panicle branches); these often protrude from a spathelike sheath at maturity. Fertile spikelets usually terminate in a twisted or bent awn. Old seed stalks, which commonly persist well into the growing season, may aid identification.

Chalky Bluestem—*Andropogon capillipes* Nash—(*A. virginicus* var. *glaucus* Hack.)

Chalky bluestem is one of the most palatable grasses available to cattle on flatwoods sites in central and south Florida. It grows in small clumps with seed stalks to 3 feet tall. Leaves and seed stalks are conspicuously glaucous (chalky), providing the plant its main distinguishing feature. Its inflorescence is almost identical to that of broomsedge bluestem. Chalky broomsedge, *Andropogon virginicus* var. *glaucopsis* (Ell.) Hitchc., grows throughout the range of chalky bluestem and westward to Louisiana, and both chalky grasses grow best on wetter sites than those usually associated with broomsedge. All three have flattened lower sheaths and nearly identical inflorescences. Taxonomic relationships between these closely related grasses, as indicated in various taxonomic manuals, are not consistent. Radford and others (1968) includes *A. capillipes* with *A. virginicus.* Godfrey and Wooten (1979) list chalky broomsedge as *A. glaucopsis* (Ell.) Nash, indicating in a key that it has a tufted ring of white hairs below each spathe of the inflorescence, which is absent in *A. capillipes.* Fernald (1950) lists chalky bluestem as *A. virginicus* var. *glaucus* Hack.

Flower stalks do not appear until September or October. Stalks and foliage provide excellent roughage for winter grazing.

Range: Florida to southern North Carolina.



Perennial. **Culms** slender, tufted, erect, to 1 m tall, glaucous, glabrous; **sheaths** crowded at base, keeled; **blades** to 60 cm long, 2 – 4 mm wide; **ligule** a ciliate membrane about 0.5 mm long; **inflorescence** narrow but loose; **spathes** purplish, glabrous, dilated, 2.0 – 3.5 cm long; **racemes** two, 1.0 – 2.5 cm long; **sessile spikelet** about 3 mm long, almost equaling pedicel of **sterile spikelet**, pedicel and rachis copiously long-villous; **awn** of sessile spikelet about 1 cm long.

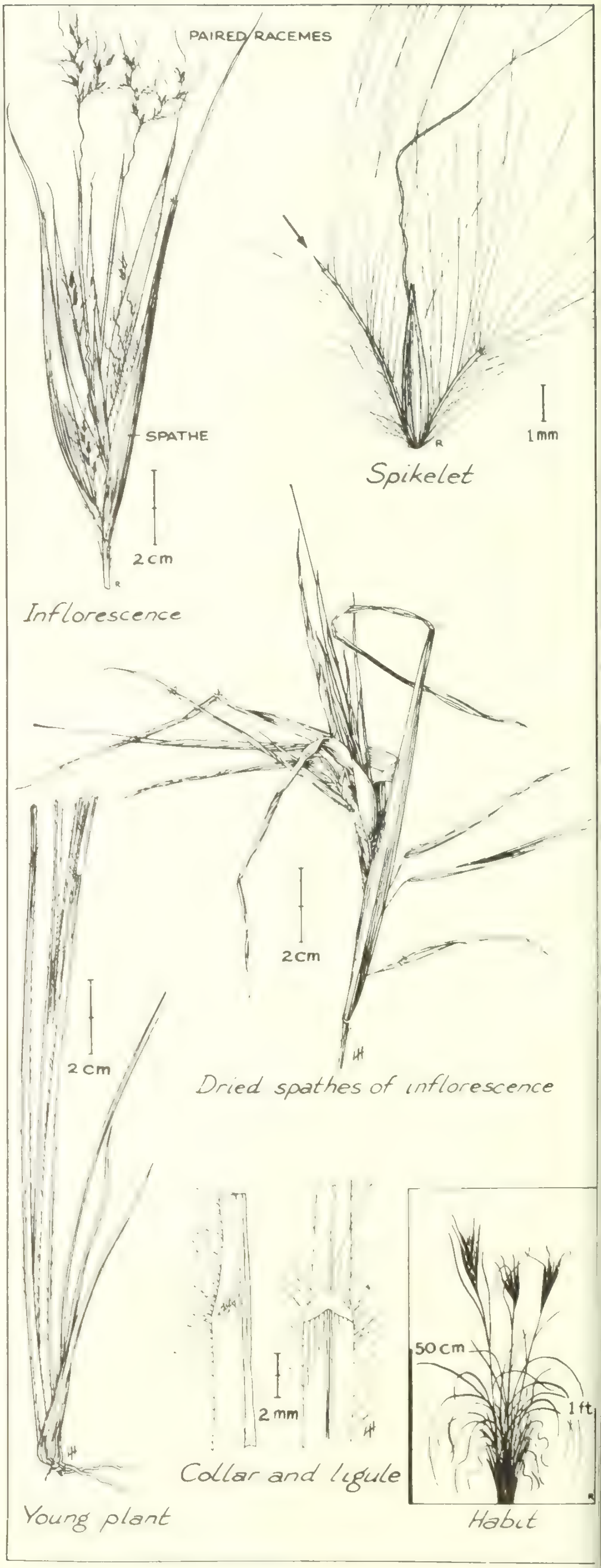
Elliott Bluestem—*Andropogon elliottii* Chapm.

Elliott bluestem, although among the least abundant southern bluestems, is one of the most conspicuous. Toward maturity the large, inflated spathes that sheathe the inflorescence give the plants a top-heavy appearance. Inner surfaces of these spathes are copper colored, smooth, and shining. On old fields and overgrazed range, Elliott bluestem may form almost pure stands, but generally is widely scattered among other grasses. While it tolerates a wide range of sites, it is most common on dry sandy soils. Typical plants are 2 to 3 feet tall with leaves about 12 inches long and ⅛ inch wide. The crowded spathes, with paired silky racemes either exserted or partially enclosed, are reliable identification features. Dead stalks, with spathes attached, often persist through the winter.

The only grass easily confused with Elliott bluestem is fineleaf bluestem. Typical fineleaf bluestem is not more than 2 feet tall with leaves less than ⅛ inch wide. Although fineleaf bluestem is often found on poorly drained soils, the two species intergrade and are often found on the same site. Intergrades not fitting the characteristics of typical Elliott bluestem are usually considered to be fineleaf. Allen (1980), however, includes *Andropogon subtenuis* as a synonym under *A. elliottii.* Although both are common, neither contributes much forage to the diet of grazing animals.

Range: Coastal Plain, Texas to New Jersey.

Perennial. **Culms** 30 – 80 cm tall, in tufts, erect, simple at first, later branching toward the summit; **sheaths** shorter than the internodes, keeled, narrow, glabrous to loosely pilose; **ligule** short, a rounded membrane less than 1 mm long; **blades** to 50 cm long, flat, keeled, 1 – 7 mm wide, glabrous to pilose, drooping and curling on drying; **racemes** 3 – 5 cm long, paired, or rarely in threes or fours, the early ones long-exserted on flexuous peduncles from slender, inconspicuous spathes, the late ones in dense clusters on short peduncles within broad, green, purplish, or coppery spathes; **sessile spikelet** 4 – 5 mm long, the awn loosely twisted, 10 – 25 mm long; **pedicellate spikelet** rudimentary, the slender rachis joints and pedicels long white-villous.



Big Bluestem—*Andropogon gerardii* Vitm.

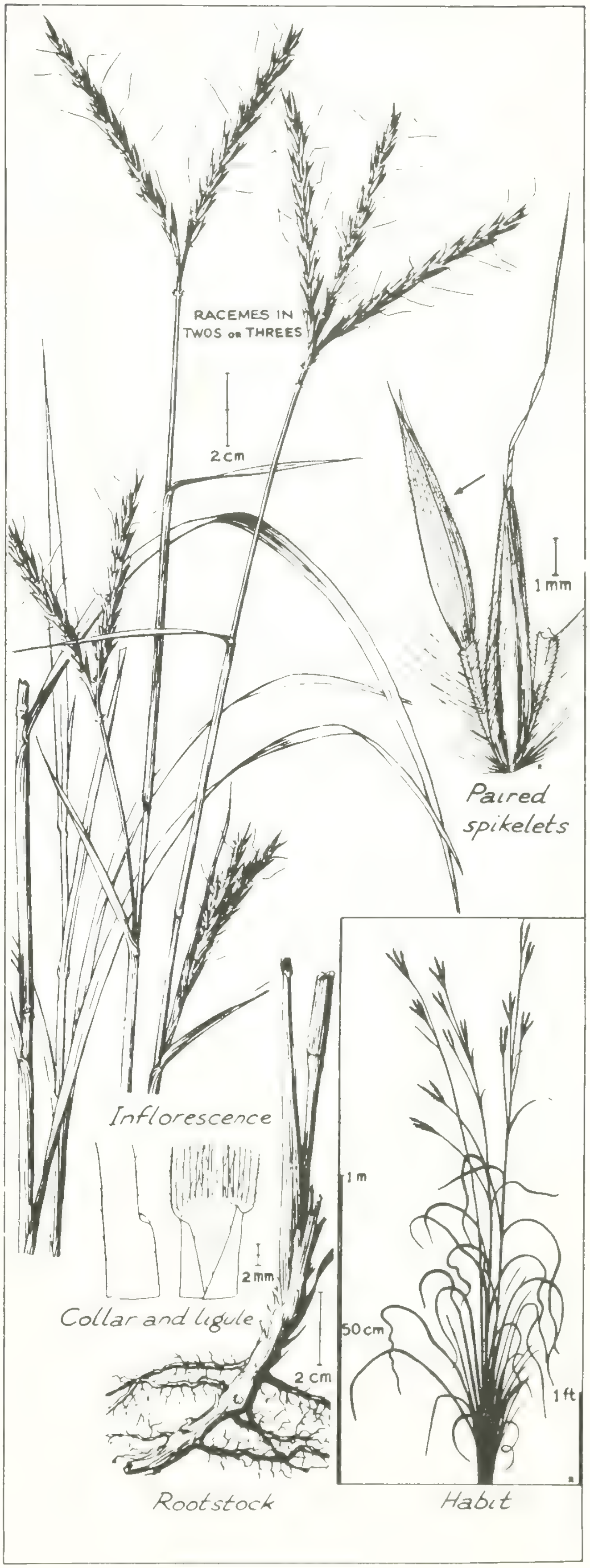
Big bluestem is the largest native bluestem in the United States, often reaching 6 feet or more in height. Although plants spread by short rhizomes, bases are often densely tufted, as in the true bunch grasses. The broad, mostly basal leaves vary from very sparsely to densely hairy. Basal shoots are usually flattened. Thick, purplish racemes are 2 to 4 inches long and generally in twos or threes. They diverge toward the tips forming a bird-foot-like inflorescence that distinguishes big bluestem from all other southern grasses, and gives it another widely known name, "turkey-foot." Identification may be difficult during much of the growing season, however, for flowers rarely appear before late summer. Because palatability is high, cattle often graze the plants closely, delaying or preventing seedstalk development.

Without seed heads, big bluestem resembles Florida paspalum, but the two can usually be distinguished by vegetative characters. In big bluestem, leaf blades narrow slightly near the collar, widening gradually toward the midsection; the lower one-third to one-half of the blade width in Florida paspalum is relatively constant. The inner surface of the big bluestem sheath is brownish to bronze, corresponding in color to the ligule, while that of Florida paspalum is green.

Because of its high yield and palatability, big bluestem is one of the four most important native forage grasses of the North American tallgrass prairie region. Others are little bluestem, indiangrass, and switchgrass (Gould 1975). On southern forest range, however, it is generally too scarce on most sites to contribute much forage. Because it is usually overgrazed when range stocking is based on the proper use of other bluestems, its presence on grazed range indicates lighter than average use.

Range: All of United States east of Idaho and Nevada.

Perennial. **Culms** stout, solid, 1 – 2 m tall, sparingly branched toward the summit; **sheaths** glabrous or villous, wider than the blade, green or purplish, sometimes glaucous; **ligule** membranous, 1 – 4 mm long, with or without a fringed margin; **blades** flat, elongate, 20 – 60 cm long, 4 – 12 mm wide, with scabrous margins and pale midveins wide and prominent near the ligules, tuft of hairs up to 1 cm long behind ligule or only short scattered hairs; **racemes** mainly in twos and threes, but up to six or more on long-exserted terminal peduncles, 5 – 12 cm long, green, yellowish or purplish, often glaucous; **sessile spikelet** perfect, 7 – 10 mm long, usually scabrous, the 1 – 2 cm long awn tightly twisted and bent; **pedicellate spikelet** not reduced, staminate, awnless.



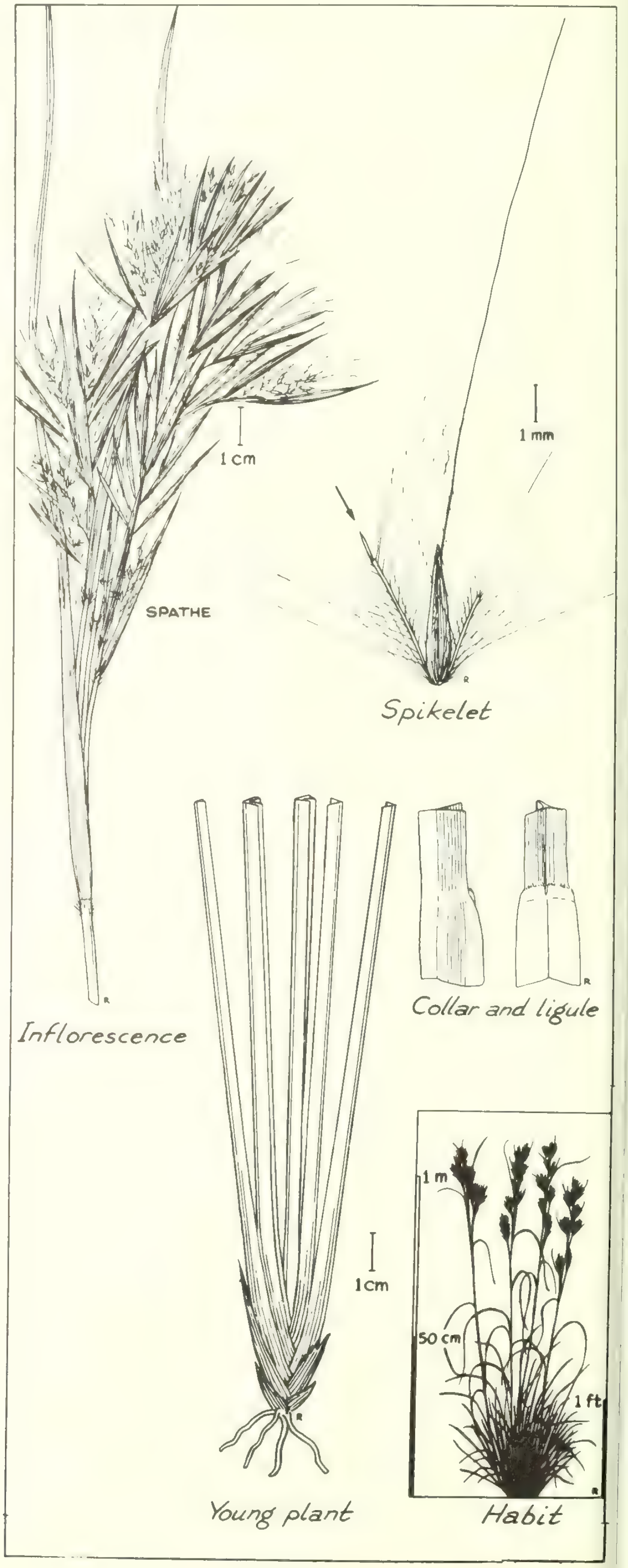
Bushy Bluestem—*Andropogon glomeratus* (Walt.) BSP.—(*Andropogon virginicus* var. *abbreviatus* (Hack.) Fern. & Grisc.)

Bushy bluestem, a stout bunchgrass 2 to 5 feet tall, occurs on low wet sites, ditchbanks, pond margins, marshes, and swamps. The inflorescence is a large, dense bundle of silky racemes with leafy spathes interspersed. Density of the seed head is due to its drastically shortened branches and internodes. Each of the many branches bears two racemes, the pair subtended by a spathe. Mature racemes are free from the spathes and equal to them in length. Individual spikelets are almost identical to those of broomsedge, and a recent plant manual included bushy bluestem under broomsedge (Radford and others 1968). Others have accepted the varietal name under broomsedge (Fernald 1950, Godfrey and Wooten 1979). The two grasses are distinct and consistent in appearance and probably deserve recognition as separate species.

Bushy bluestem is not considered a valuable forage plant on pine ranges as it occurs on sites not generally grazed.

Range: Southern California and Nevada, extending east to Florida, Kentucky, and Massachusetts.

Perennial. **Culms** erect, stout, to 8 mm thick, 50 – 150 cm tall, compressed, bushy-branching above; **sheaths** longer than the internodes, flattened, rough, often pubescent in the throat, ciliate on the margins; **ligule** membranous, about 1 mm long, with a truncate, fimbriate margin; **inflorescence** dense, composed of a mass of slightly dilated spathes; **racemes** paired, 1 – 3 cm long from spathes of about the same length; **sessile spikelet** 3 – 4 mm long, the awn straight, 1.0 – 1.5 cm long; **pedicellate spikelet** reduced to a single subulate glume or absent, its pedicel and the rachis joint silky-villous and about the same length as the sessile spikelet.



Inflorescence

Spikelet

Collar and ligule

Young plant

Habit

Hairy Bluestem—*Andropogon longiberbis* Hack.

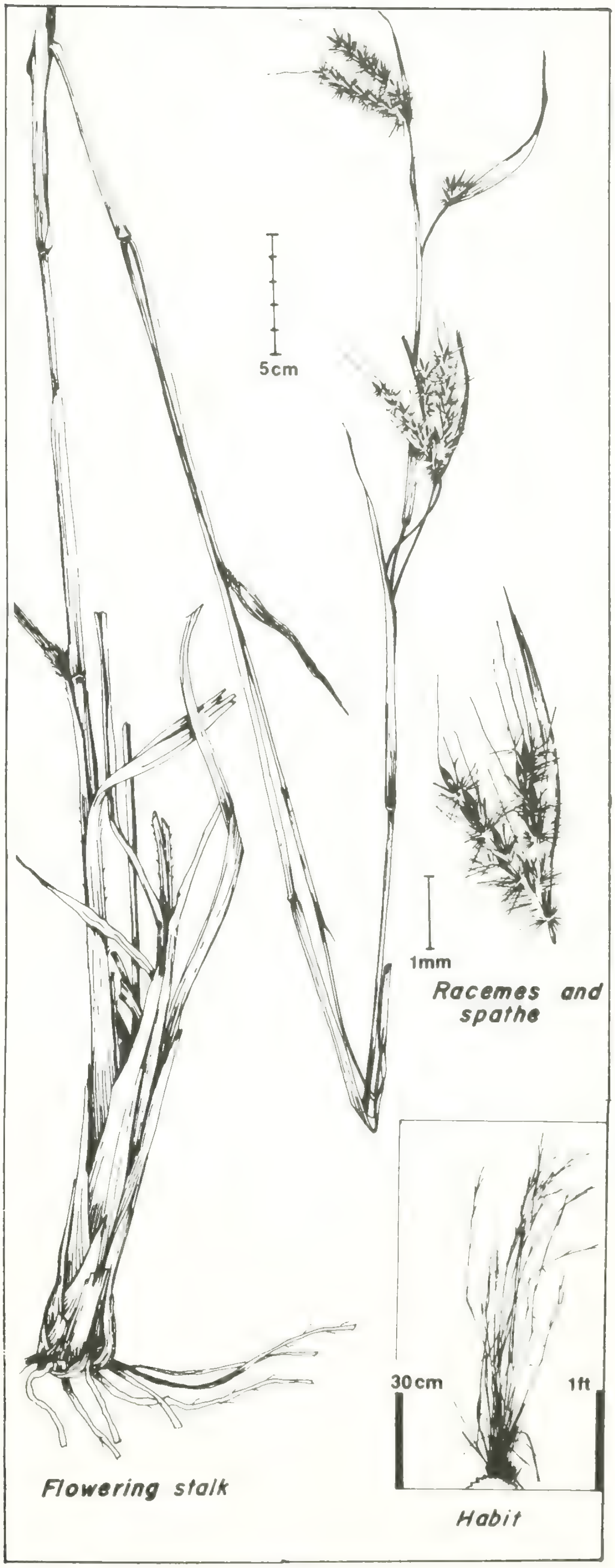
Hairy bluestem is closely related to broomsedge bluestem, but is generally more hairy, especially the seed heads. Lower leaf sheaths and blades are often woolly with silvery hairs and are not strongly flattened like those of broomsedge.

It is most important in south Florida, where it is abundant on flat, sandy-slough sites, which are covered with shallow slow-moving water during the wet summer season. These sites are usually grazed heavily during late winter and early spring following a burn. Leaves and emerging flower stalks are eaten by cattle from February through June.

A similar grass, *Andropogon tracyi* Nash, grows within the range of hairy bluestem and also extends along the Gulf Coastal Plain to Louisiana. Foliage is generally less hairy than that of *A. longiberbis,* and the stalk (peduncle) supporting each pair of racemes is from ½ to 1¼ inch long; peduncles of *A. longiberbis* are less than ½ inch long.

Range: Georgia and Florida.

Perennial. **Culms** to 1 m tall, glabrous; lower **sheaths** gray-villous, upper glabrous; **blades** 2 – 5 mm wide, elongate, lower blades densely grayish-villous ventrally, greenish and sparsely villous dorsally; **racemes** two to four, 2 – 3 cm long, densely villous; **peduncle** less than 1 cm; **spathe** 3 – 5 cm long, enclosing peduncle and bases of racemes, light brown at maturity; **sessile spikelet** 3 mm long; **awn** straight, about 1 cm long.



Fineleaf Bluestem—*Andropogon subtenuis* Nash

Fineleaf bluestem is among the smallest southern bluestems. It is fairly common and widely distributed, but its small size and narrow leaves make it relatively inconspicuous. It occupies a variety of sites, but grows best on well-drained ridges, mounds, and slopes. On cutover areas it may comprise 25 percent of the grass stand, but generally much less. Like slender bluestem, it tolerates heavier grazing than taller, broad-leaved grasses.

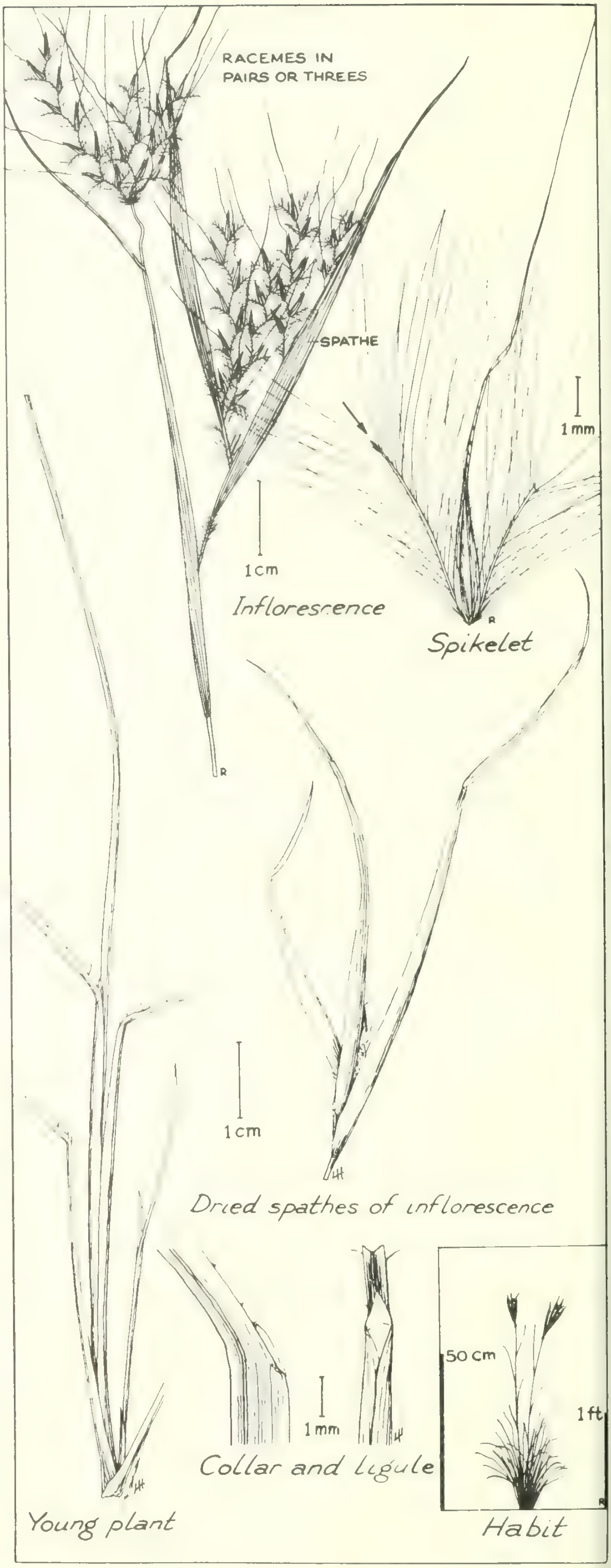
Mature plants are 16 to 28 inches tall and leaves are less than ⅛ inch wide. Lower leaf sheaths are laterally flattened, as in many bluestems. Foliage is similar to that of slender bluestem. Under a hand lens, fineleaf bluestem is distinguishable by its pointed ligule, the ligule of slender bluestem being short and blunt.

Seed heads are borne in slender, slightly inflated spathes, with at least some of the slender, silky racemes protruding. Seed heads may be confused with those of Elliott bluestem, which intergrades with fineleaf bluestem. Spathes of Elliott bluestem are distinctly inflated; they are also longer, more numerous, and more closely crowded.

In forage quality, fineleaf bluestem is similar to slender bluestem, with which it can be easily confused when both grasses are grazed short. Of the two, fineleaf bluestem matures later and is more palatable in summer.

Range: Louisiana to northern Florida.

Perennial. **Culms** erect, in small tufts, very slender, somewhat compressed, 40 – 70 cm tall, sparingly branched above; **sheaths** keeled, wider than the blade, generally glabrous, but occasionally densely long-villous; **ligule** 0.5 – 1.0 mm long, sharply pointed; **blades** 1.5 – 2.0 mm wide, flat or folded, scabrous, generally with long scattered hairs on the margins near the ligule, occasionally densely long-villous; **racemes** two, 2 – 3 cm long, flexuous, from slightly inflated spathes rarely over 7 – 10 cm long; **sessile spikelet** about 4 mm long; **pedicellate spikelet** reduced to a tiny scale on a pedicel much longer than the sessile spikelet.



Paintbrush Bluestem—*Andropogon ternarius* Michx.

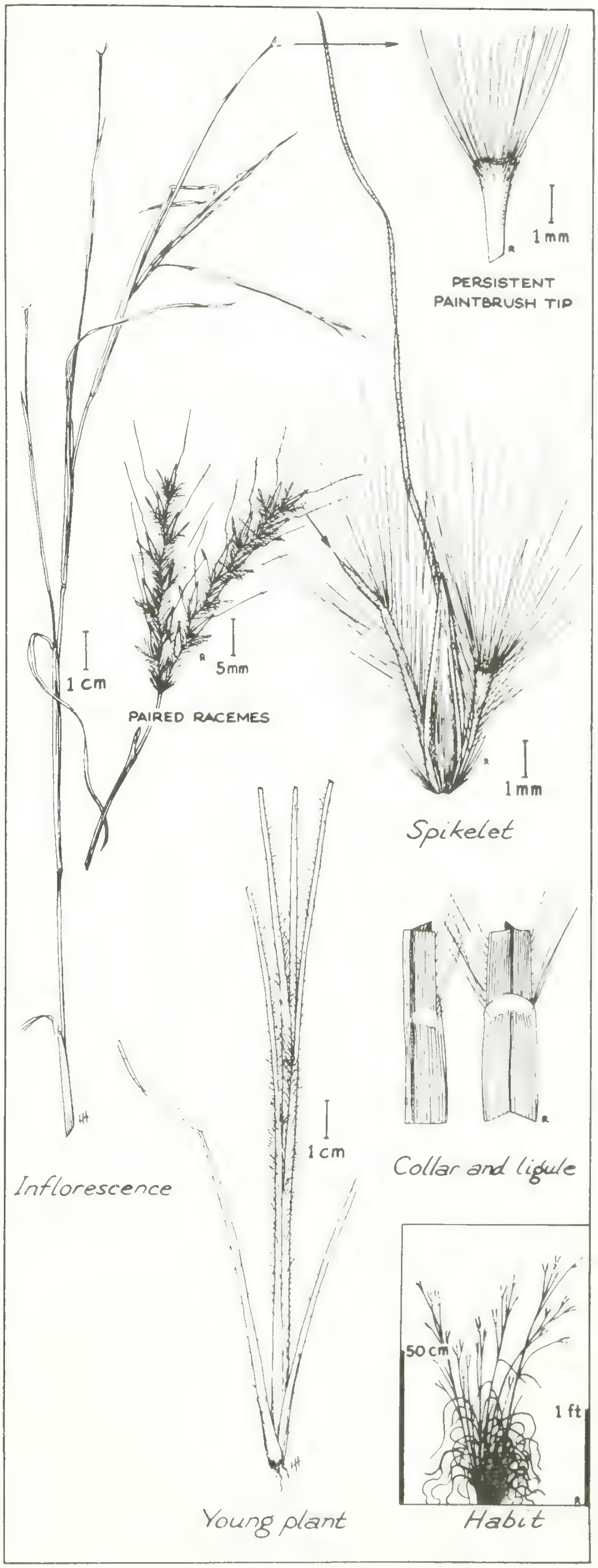
Paintbrush or "splitbeard" bluestem is a common associate of little bluestem, especially on well-drained sandy sites. The two grasses resemble each other until flower heads emerge in early fall. Racemes of paintbrush bluestem are paired. They are silky and much thicker and showier than those of little bluestem, which has only one raceme terminating each inflorescence branch.

Persistent old seedstalks are the best character for distinguishing paintbrush bluestem during winter, spring, and summer. A conspicuous paintbrushlike tuft of hairs remains on the branch tips after racemes shatter, and old-growth basal leaves are curly.

Paintbrush bluestem is similar in forage value to little bluestem. Because it is seldom abundant, however, it contributes little to the cattle diet.

Range: Coastal Plain, Delaware to Texas, extending inland on dry sandy soils to Kentucky and Kansas.

Perennial. **Culms** in tufts, 80 – 120 cm tall, simple below and much branched above; **sheaths** shorter than the internodes, glabrous to densely hirsute near the base; **ligule** about 1 mm long, membranous; **blades** 2 – 4 mm wide, the lower long and curling on drying; **racemes** in pairs, occasionally in threes, 3 – 6 cm long, silvery-silky, with long hairs, more or less exserted on long slender peduncles from slender spathes; **sessile spikelet** 5 – 6 mm long, the twisted and bent awn 1.5 – 2.0 cm long; **pedicellate spikelet** a scabrous scale about 1 mm long on a densely villous pedicel almost as long as the sessile spikelet.



Broomsedge Bluestem—*Andropogon virginicus* L.

Broomsedge bluestem—usually called broomsedge—is a coarse, practically hairless bunchgrass about 3 feet tall. It is one of the most common grasses in the South as its light, windblown seeds invade old fields, roadsides, and overgrazed ranges. The basal leaf sheaths are strongly flattened and colorless or yellow; the rest of the plant is greenish yellow. A glaucous variety, chalky broomsedge, *Andropogon virginicus* var. *glaucopsis* (Ell.) Hitchc., is common on poorly drained sites of the lower Coastal Plain. The two forms may grow on the same site.

Although best known as an old-field invader, broomsedge occurs throughout the piney woods, even on ungrazed ranges. It is most common on sandy sites, but grows on a wide range of soils. On cutover longleaf pine ranges it often inhabits stump holes.

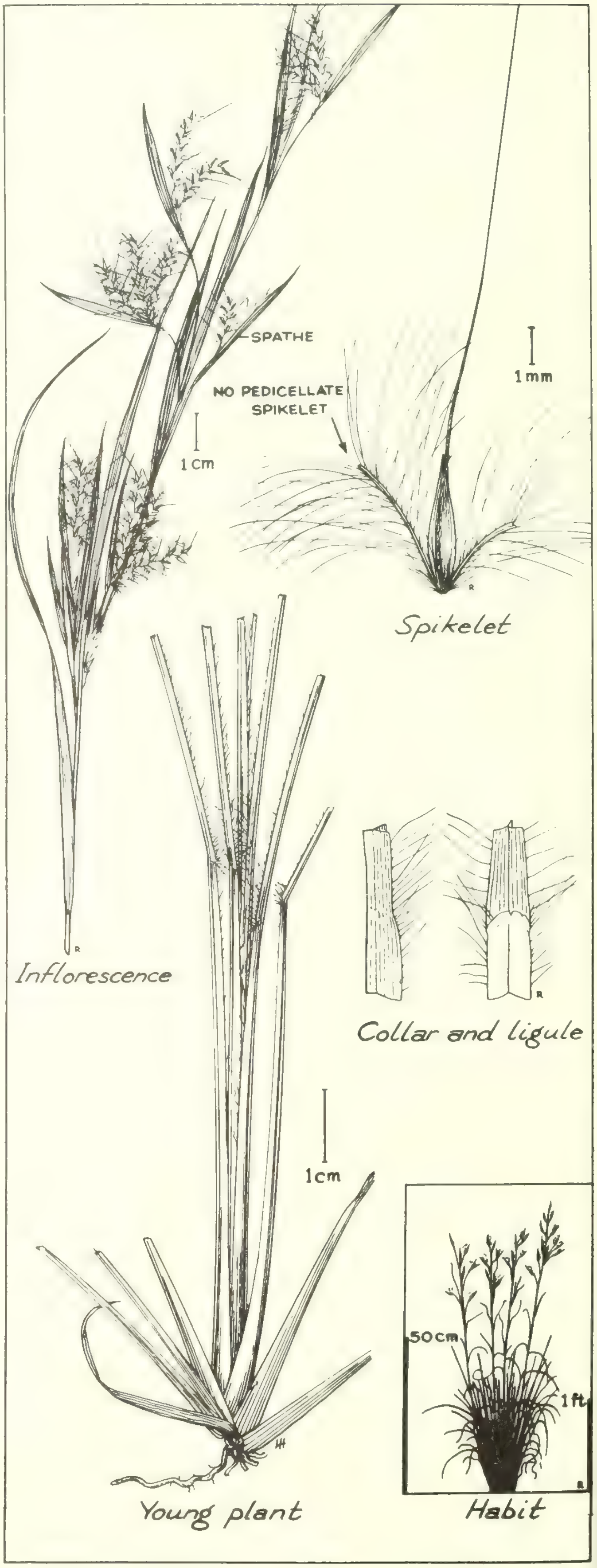
Inflorescence branches are numerous, each bearing two to four slender silky racemes about 1 inch long. A spathe partly encloses each raceme. Broomsedge can be distinguished from its close relatives, Elliott bluestem, fineleaf bluestem, and bushy bluestem, by its extremely flat basal sheaths and yellow-green or blue-gray color.

Except on wet sites and abandoned fields, it is seldom abundant enough to contribute much forage. Where surface drainage is moderately slow, however, the chalky broomsedge variety is valuable as forage, especially in the fall.

Several closely related species occur with broomsedge in the Southeast. Chalky bluestem of the Atlantic Coastal Plain is similar to chalky broomsedge. Hairy bluestem, an early flowering grass of south and central Florida and south Georgia, has grayish, hairy foliage. Inflorescences are similar to those of broomsedge, although three or four racemes may be found on some branches; broomsedge has only two racemes per branch and lower sheaths are usually glabrous, flattened, and yellow to yellow-green in color. Intergradations between the silky-racemed bluestems may be encountered.

Range: Throughout most of the eastern half of the United States; also reported from California.

Perennial. **Culms** erect, 50 – 100 cm tall, often in large tufts, simple at the base, branched above; **sheaths** shorter than the internodes, compressed, hirsute on the margins, otherwise glabrous and shining, conspicuously equitant and flat in mature plants, less so in young ones; **ligule** membranous, short, ciliate; **blades** flat or folded, 2 – 5 mm wide, 15 – 40 cm long, pilose on the upper surface near the base; **racemes** two to four, 2 – 3 cm long, partly included and shorter than the coppery, slightly inflated spathes; **sessile spikelet** glabrous, about 3 mm long with an awn 1 – 2 cm long; **pedicellate spikelet** generally obsolete, the pedicel long-silky-villous.



Little Bluestem—*Schizachyrium scoparium* (Michx.) Nash—(*Andropogon scoparius* Michx.)

Little bluestem occurs across the United States in a complex of ecotypic variations that has been incompletely and inconsistently classified. Generally, the western and northern forms have glabrous foliage, while those found in the South, including pinehill bluestem, *Schizachyrium scoparium* var. *divergens* (Hack.) Gould, have varying degrees of foliage pubescence (McMillan 1964). On cutover or open forest sites in the longleaf - slash pine - bluestem type, little bluestem is usually a major forage plant, often producing over 50 percent of the forage.

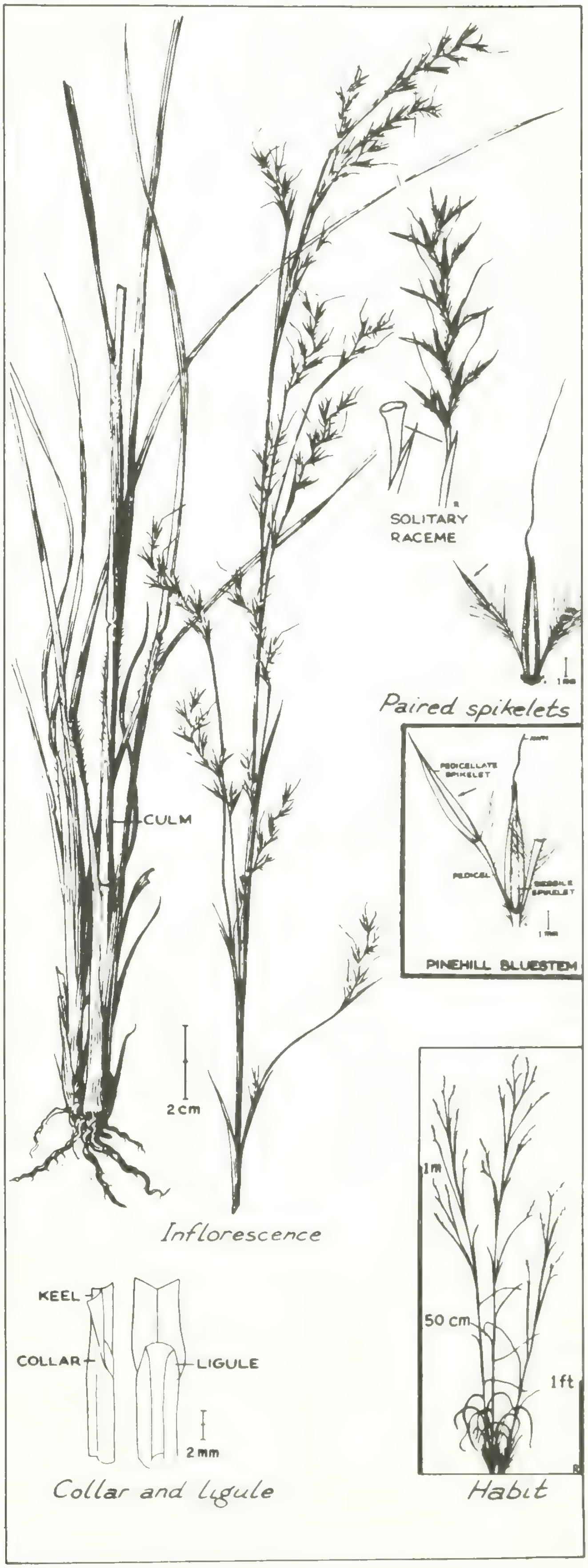
Pinehill bluestem, or eastern little bluestem (Gould 1975), which is the common form of *S. scoparium* in Louisiana and east Texas, differs from typical little bluestem by its unreduced pedicellate spikelet, which may be sterile or staminate. The pedicellate spikelet in little bluestem is a sterile rudiment.

Protein content of new growth is high in spring or following a fire anytime during the growing season. Quality drops rapidly, usually becoming deficient by midsummer. Phosphorus is deficient yearlong. Palatability remains relatively high throughout the growing season; during winter the standing residue provides excellent roughage for cattle being fed a protein supplement.

In Alabama, Georgia, and northern Florida, little bluestem may be confused with creeping bluestem which is rhizomatous. Pinehill bluestem may have short rhizomes, but little bluestem is generally considered a bunch grass.

Range: Found in all but the Pacific Coastal States and Nevada.

Perennial. **Culms** erect, 20 – 150 cm tall, tufted; **rhizomes** occasionally present, short, knotty; **foliage** glabrous to villous, green to glaucous; **sheaths** (lower) laterally compressed and keeled; **blades** 25 – 60 cm long; 3 – 6 mm wide; **racemes** one per inflorescence branch, 3 – 6 cm long; **sessile spikelet** six to eight per raceme, fertile, 6 – 8 mm long; **awn** 8 – 15 mm, paired with **pedicellate spikelet** reduced to sterile rudiment in some varieties, unreduced and sometimes staminate in variety *divergens*.



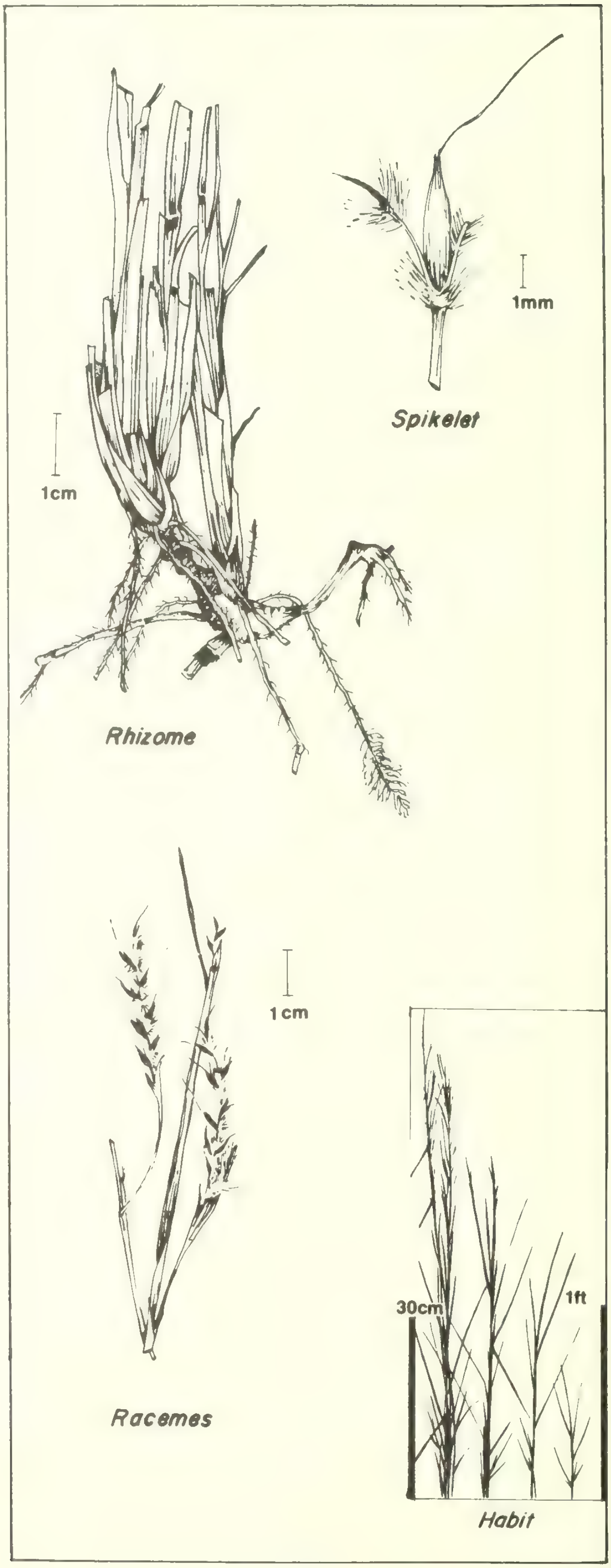
Creeping Bluestem—*Schizachyrium stoloniferum* Nash—(*Andropogon stolonifer* (Nash) Hitchc.)

Creeping bluestem, a close relative of little bluestem, has never been considered a part of the *Schizachyrium scoparium* complex, although the two species reportedly intergrade (Godfrey and Wooten 1979). Its creeping rhizomes separate it from associated forms of little bluestem. Creeping bluestem is one of the major forage grasses of the longleaf-slash pine-wiregrass type, growing in association with pineland threeawn, the common "wiregrass" of the sandy soils of Florida and Georgia. In southern Florida, creeping bluestem may be associated with south Florida bluestem, *S. rhizomatum* (Swallen) Gould. The latter is a smaller grass, usually less than 30 inches tall, with leaf blades ⅛ inch wide or less. South Florida bluestem has shorter rhizomes than creeping bluestem. Inflorescence characteristics of the two grasses are similar, but the axis of the raceme of *S. rhizomatum* is conspicuously curved-zigzag.

Creeping bluestem, like little bluestem, provides excellent forage during spring and early summer. Palatability remains high in winter, and the standing cured forage provides good quality winter roughage for cattle if supplemental nutrients are furnished.

Range: Southern Georgia, Florida, and Alabama.

Perennial. **Culms** to 150 cm tall, solitary or few in a tuft, rhizomatous; **leaves** up to 5 mm wide, elongate; **foliage** glabrous to villous; **racemes** solitary, 3 – 4 cm long; **sessile spikelet** 5 – 7 mm long; **pedicellate spikelet** rudimentary.



Slender Bluestem—*Schizachyrium tenerum* Nees—(*Andropogon tener* (Nees) Kunth)

Slender bluestem is usually the most abundant and important forage plant on cutover longleaf pinelands. As the name suggests, it is fine-stemmed and narrow-leaved; another common name is "wiregrass." The wiry flower stalks are up to 3 feet long but have a sprawling habit, rarely exceeding 1.5 feet in height. In the growing season following a burn, flower stalks grow upright. Slender bluestem grows on a variety of sites, but is most productive on well-drained soils.

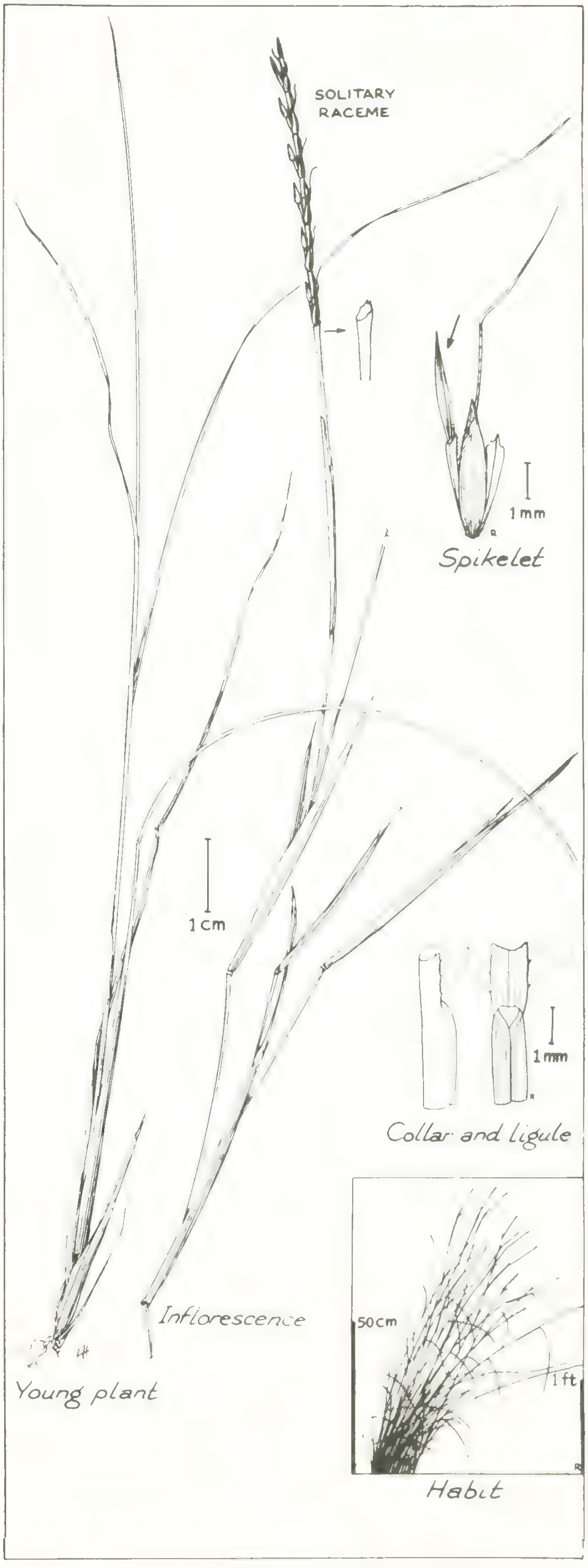
Each flower stalk branch bears a single, slim, practically hairless raceme about 2 inches long. The racemes appear in early summer and shatter soon after maturity. Thereafter, plants can be identified by the slightly enlarged oblique tips of flower stalk branches.

Slender bluestem grows mixed with other grasses. In favorable years on cutover sites its dense mass of reclining seedstalks obscures and may smother other species, creating the appearance of extensive pure stands. As it does not tolerate heavy shade, abundance decreases following reforestation of cutover lands.

On nontimbered sites, this grass is important in the cattle diet. It matures much earlier than most associated grasses and, unless grazed closely, becomes fibrous and unpalatable by midsummer. An accumulation of old growth not only discourages grazing but interferes with growth, thereby reducing herbage production. Where a heavy rough develops, burning may materially improve grazing value.

Range: Texas and Oklahoma to Florida and Georgia.

Perennial. **Culms** 60 – 100 cm long, slender, in tufts, reclining, the upper half sparingly branched; **sheaths** shorter than the internode, broader than the blade, glabrous; **ligule** less than 1 mm long, edge smooth; **blades** about 1 mm wide, flat or loosely involute, glabrous except for sparse, fine hairs at the base; **racemes** solitary, 2 – 6 cm long, glabrous, on long peduncles with slightly flared, obliquely pointed tip; **sessile spikelet** 4 – 5 mm long, the awn 7 – 10 mm long, twisted and bent; **pedicellate spikelet** 4 – 5 mm long, awnless, empty, or sometimes staminate.



Panicum Grasses—*Panicum* spp., *Dichanthelium* spp.

The genus *Panicum*, as outlined in Hitchcock's manual (Hitchcock 1950), consisted of three subgenera, two of which were represented by numerous species throughout the South. Subgenus *Dichanthelium*, the "low" panicums, were those that flowered in spring and again in late summer, with distinct winter, spring, and fall phases; subgenus *Eupanicum*, the "true" panicums, flowered once yearly, whose vegetative appearance did not change appreciably during the growing season. The panicums have been revised in recent years, especially in *Dichanthelium*, which has become the genus for low panicums, and species have been combined to reduce the total number from over 100 to 26 (Gould and Clark 1978). The true panicums of subgenus *Eupanicum* remain in the genus *Panicum*.

Although the revision reduced the number of species, the low panicums remain one of the largest genera of grasses in the South. While they do not produce as much forage as the bluestems, they are often a high-quality component of the diet for deer and cattle in late winter or early spring before other grasses begin new growth. Crude protein of early growth may exceed 15 percent. Mature green leaves contain around 8 percent protein, almost as high as new growth of bluestems. The true panicums, which include switchgrass, beaked panicum, and maidencane, are generally higher in nutrient content than the bluestems.

The panicums included here are those considered important because of wide distribution, general abundance, or unusually high forage value within a range type.

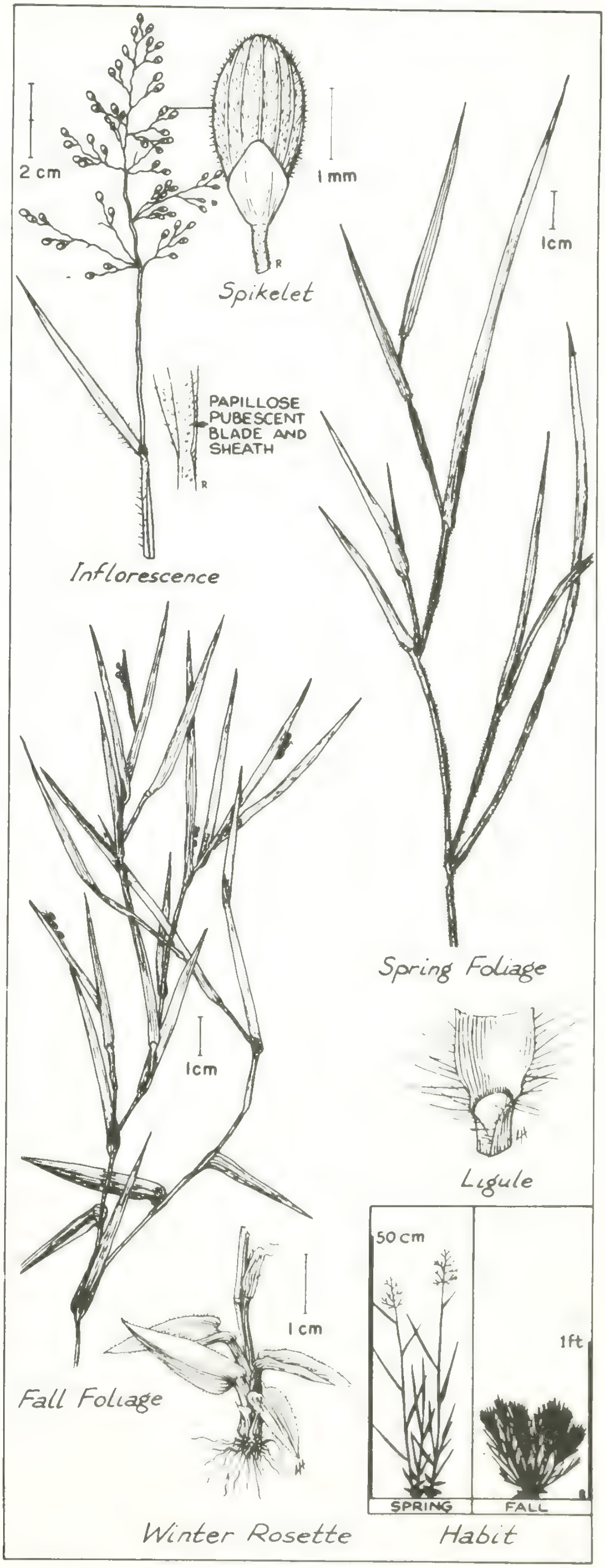
Needleleaf Panicum—*Dichanthelium aciculare* (Desv. ex Poir.) Gould & Clark—(formerly *Panicum aciculare* Desv. ex Poir. and *P. angustifolium* Ell.)

Considered as two separate *Panicum* species before the *Dichanthelium* revision, needleleaf panicum, *P. aciculare*, and narrowleaf panicum, *P. angustifolium*, were combined along with about 20 other names under the name *Dichanthelium aciculare*. The common name associated with *P. aciculare* was retained.

Needleleaf panicum, as now interpreted, is the most common low panicum on sandy longleaf-slash pine sites. Leaves and stems may be 6 inches long and over $^{1}/_{4}$ inch wide, hairy or hairless, and autumnal leaves may be tightly rolled. Spikelets are $^{1}/_{16}$ to $^{1}/_{8}$ inch long and minutely hairy or hairless. Because of the numerous former taxa combined under this species and the wide geographical range included, considerable variation must be allowed in all plant characteristics.

Range: Texas to Florida, extending north to Missouri, Indiana, and Massachusetts.

Perennial (spring phase). **Culms** usually stiffly erect, 25 – 75 cm tall, glabrous or moderately pubescent or pilose but the nodes not truly bearded, often branching freely above with age, producing fascicles of reduced leaves and panicles, the leaves narrow, often involute; **sheaths** glabrous, pubescent, or pilose, occasionally with long, papillate hairs; **ligule** usually a fringe of hairs 1 mm or less long; **leaves** firm or stiff, narrowly lanceolate, usually acuminate, glabrous or hairy, 6 – 20 cm long and 2 – 8 mm broad, sometimes becoming tightly involute; **panicles** open or tightly contracted, mostly 4 – 9 cm long; **spikelets** elliptic-ovate to obpyriform or fusiform, glabrous or puberulent, 1.9 – 3.6 mm long; **first glume** about half as long as the spikelet.



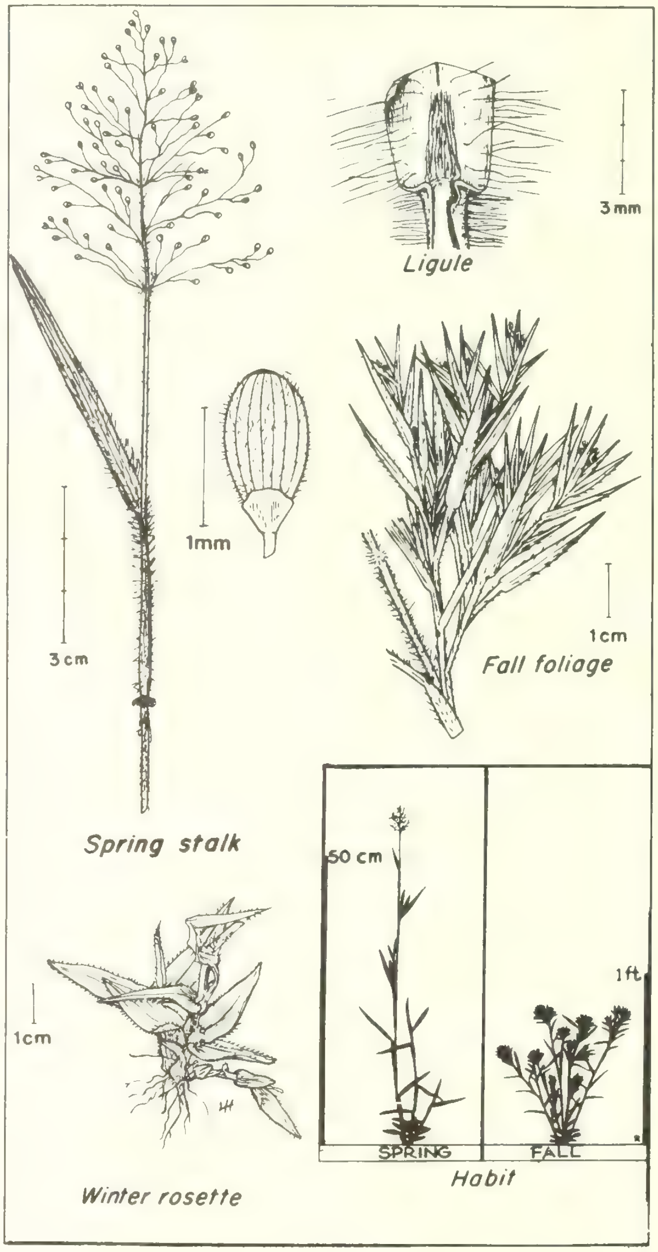
Woolly Panicum—*Dichanthelium acuminatum* (Swartz) Gould & Clark var. *acuminatum*—(*Panicum lanuginosum* Ell.)

Approximately 70 former species or varieties of hairy low panicums were placed in four varieties of *Dichanthelium acuminatum* by Gould and Clark. More than 40 plant names were combined under the variety *acuminatum*. Several varieties of *D. acuminatum*, including Lindheimer panicum, are almost hairless. In this handbook, *D. acuminatum* var. *acuminatum* will represent the "woolly" varieties and var. *lindheimeri* the nearly hairless varieties of *D. acuminatum*.

Woolly panicum grows throughout North America on sandy woodland soils. It is a consistent, although minor, component of the forage in open southern pine forests. Like other low panicums, it exhibits the three seasonal growth forms and provides limited early green forage.

Range: British Columbia and Quebec to California and Florida; Central and South America.

Perennial (spring phase). **Culms** usually in large clumps, 15 – 60 cm tall, usually densely villous below with long, soft hairs, these often minutely papillate; **leaves** variously pubescent to nearly glabrous, 5 – 10 cm long and 5 – 12 mm broad, the hairs soft or coarse, usually long; **sheaths** shorter than the internodes, soft-villous or puberulent on the back, ciliate on the margins; **ligules** well developed with hairs mostly 2 – 4 mm long; **panicles** 5 – 8 cm long, loosely-flowered, commonly pubescent on the main axis and lower branches; **spikelets** pubescent, elliptic-obovate, 1.6 – 2.5 mm long; **first glume** about as broad as long, one-third as long as the spikelet, broadly pointed to somewhat rounded at the apex.



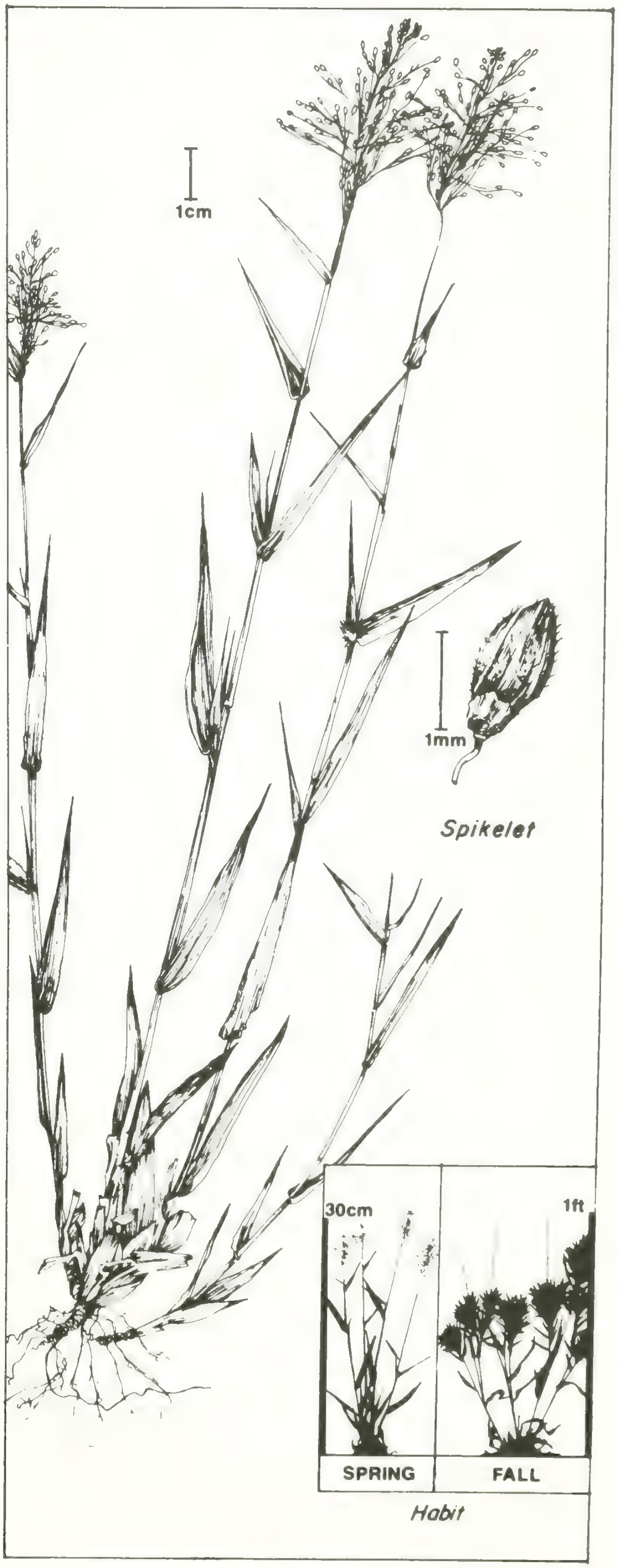
Lindheimer Panicum—*Dichanthelium acuminatum* var. *lindheimeri* (Nash) Gould and Clark—*(Panicum lindheimeri* Nash)

This low panicum is common in dry sandy woods throughout the eastern half of the United States. Spring flower stalks are 1 to 3 feet tall. Leaf blades are ascending, 1 to 4 inches long and 1/5 to 2/5 inch wide. The ligule is a dense ring of hairs 1/5 inch long, easily seen with the naked eye. The panicle is 1½ to 2½ inches long with spikelets less than 1/16 inch in length. The tiny spikelets and the hairy ligule are good distinguishing characteristics for this grass.

Fall foliage consists of stiffly spreading, often prostrate stems made top-heavy by crowded branches of small leaves. Fall leaves average about 1 inch long and 0.1 inch wide.

Range: Texas to Minnesota and eastward; also New Mexico, California, and Oregon.

Perennial (spring phase). **Culms** tufted, stiffly ascending or spreading, 30 – 90 cm tall; **blades** lanceolate 3 – 15 cm long, 3 – 15 mm wide; **sheaths** ciliate on margins; **ligule** a tuft of white hair 4 – 5 mm long; **panicle** 4 – 7 cm long, about as wide; **spikelets** 1 – 2 mm long, puberulent.



Delicate Panicum—*Dichanthelium dichotomum* var. *ensifolium* (Baldw.) Gould & Clark—(*Panicum chamaelonche* Trin.)

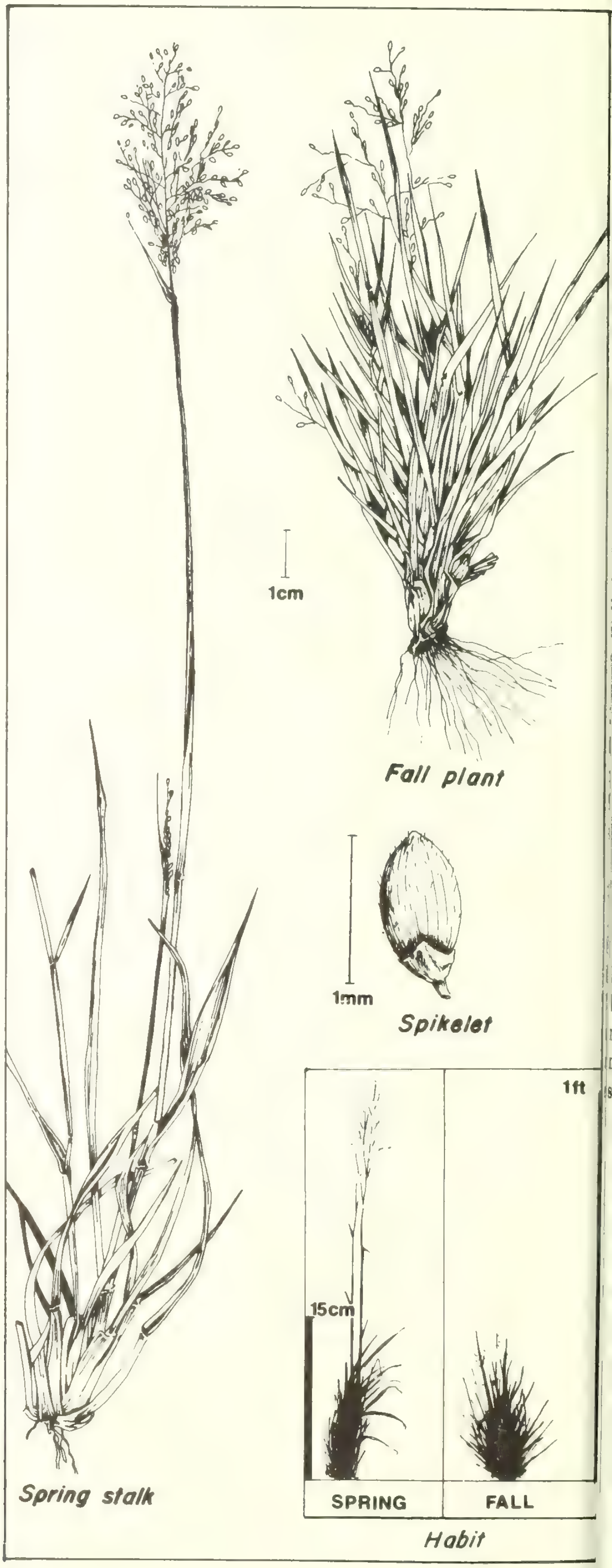
As its common name indicates, this low panicum is a small, slender grass, seldom exceeding 18 inches in height. Spring plants form dense tufts, and freely branching fall growth forms dense cushions; on low sandy sites with little competition, fall clumps may grow to 20 inches in diameter. It is found on wet seeps, marshy areas, and acid bogs, usually in shade.

Foliage of delicate panicum is hairless and makes excellent forage, although it seldom contributes a significant amount to the cattle diet. In south Florida, plants remain partially green during winter. Winter rosettes furnish some green winter forage for deer. Seeds, though tiny, are eaten by quail.

Spring plants have leaf blades ½ to 1½ inches long, and panicles are 1 to 2 inches long. Seeds are among the smallest of the panicums, only slightly more than 1/16 inch long. Numerous similar, closely related panicums were combined under *Dichanthelium dichotomum* in the Gould and Clark (1978) revision. Approximately 50 *Panicum* species or varieties, including *P. glabrifolium* Nash, a similar but larger plant found in south Florida, were assigned among five varieties of *Dichanthelium dichotomum. Panicum glabrifolium* is now *D. dichotomum* var. *glabrifolium* (Nash) Gould & Clark.

Range: Texas and Arkansas to Florida and New Jersey.

Perennial (spring phase). **Culms** densely tufted, to 45 cm tall, ascending; **blades** firm, 1.5 – 4.0 cm long, 2 – 3 mm wide; **panicle** 2 – 6 cm long; **spikelets** 1.1 – 1.5 mm long, glabrous.



Wideleaf Panicum—*Dichanthelium latifolium* (L.) Harvill—(*Panicum latifolium* L.)

Wideleaf panicum is a low panicum in rocky or sandy woods of the northern portion of the loblolly-shortleaf pine-bluestem type. Plants may be over 3 feet tall with leaves 7 inches long and 1½ inches wide. Except for scattered hairs on lower stems and sheaths, foliage is hairless, including stem joints. Panicles are up to 6 inches long with spikelets about ⅛ inch long.

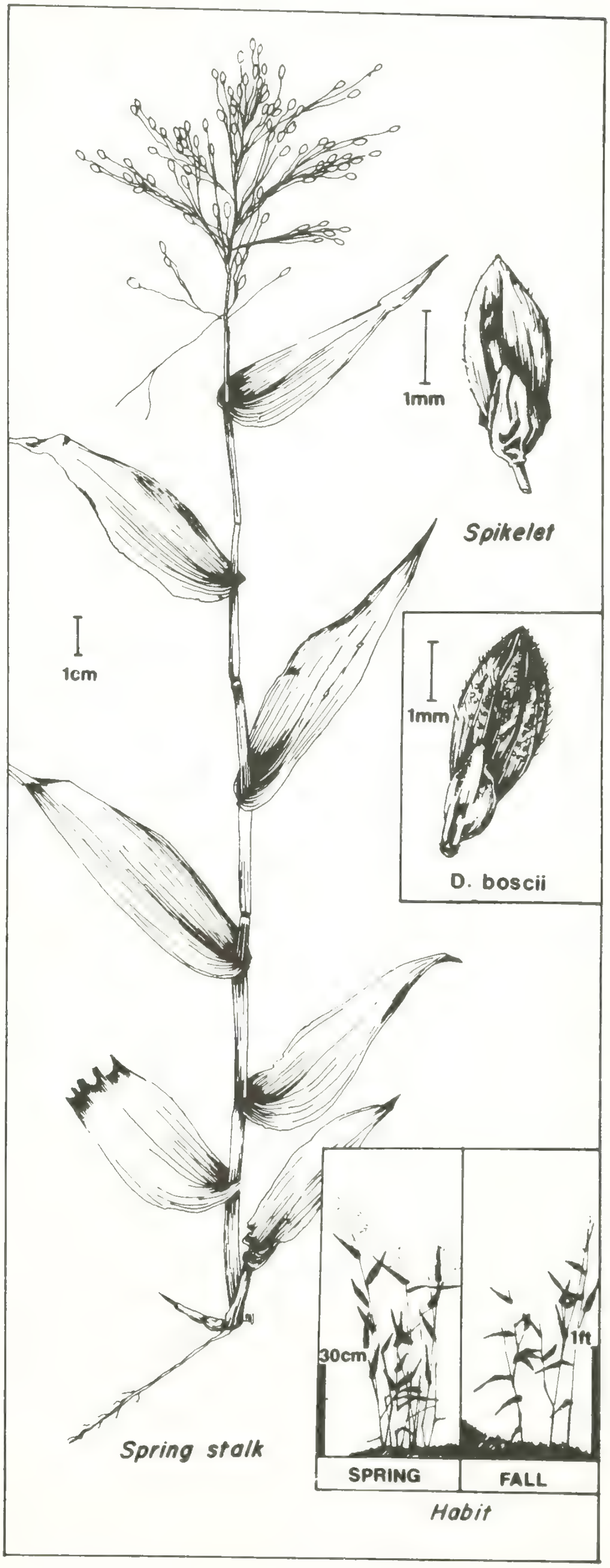
Another broadleaf panicum, *Dichanthelium boscii* (Poir.) Gould, found throughout the southern states, is similar to wideleaf panicum. Stem joints are bearded in *D. boscii,* however, and spikelets are larger. These two grasses have the broadest leaves of all low panicums, and their spikelets are among the largest. Autumn foliage is crowded on top-heavy, branched stems; leaves are about the same size as those produced in spring.

Velvet panicum, *D. scoparium* (Lam.) Gould, is one of the coarsest and tallest of low panicums, reaching a height of 4 to 5 feet on favorable sites such as sandy ditches and swales throughout the South. Leaves are not as wide and spikelets not as large as those of *D. latifolium* and *D. boscii.* Velvet panicum is seldom found on burned or grazed forest range.

A common broadleaf low panicum of shaded loblolly-shortleaf pine-hardwood sites that may be confused with wideleaf panicum is variable panicum, *D. commutatum* (Schult.) Gould. It is found also in river bottoms and other moist shaded sites throughout the eastern and Gulf Coastal States.

Range: Arkansas to northern Georgia, extending northward to Canada.

Perennial (spring phase). **Culms** 45 – 100 cm tall, glabrous or sparsely pubescent toward base, nodes glabrous; **sheaths** ciliate; **blades** 8 – 18 cm long, 3 – 35 mm wide, thin, glabrous; **ligule** a minute fringed membrane, rarely 1 mm long; **panicle** 6 – 20 cm long; **spikelets** 3.3 – 3.8 mm, puberulent to nearly glabrous.



Little Panicum—*Dichanthelium leucoblepharis* var. *glabrescens* (Griseb.) Gould & Clark—*(Panicum polycaulon* Nash)

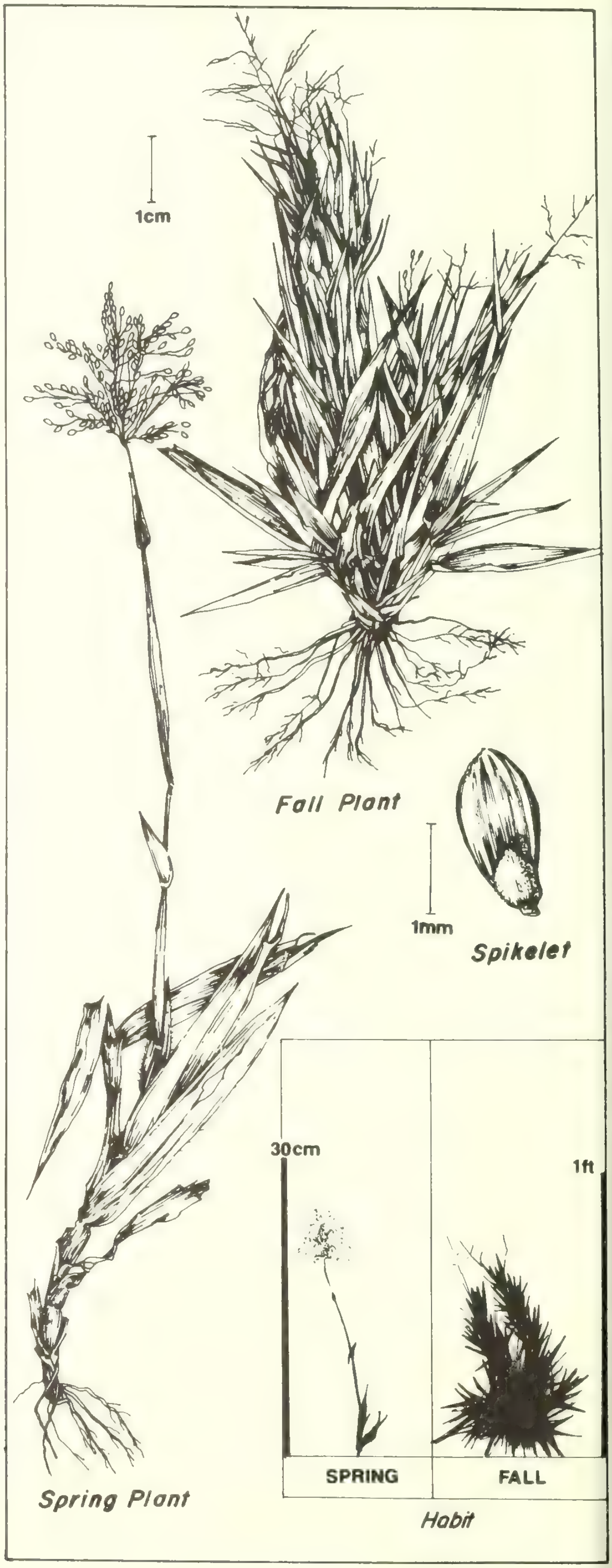
This low panicum rarely exceeds 6 inches in height. In the pine flatwoods of the Coastal Plain where it commonly occurs, it is usually the smallest panicum. Winter rosette leaves are about 3 inches long and ¼ inch wide. Later spring leaves are about half that size, and those just below the inflorescence are often less than ½ inch long. Foliage is light green and soft, often turning purplish after flowering heads are produced. Except for ciliate hair on leaf margins, foliage is glabrous. Spring panicles, which are about 1½ inches long and 1 inch wide, also turn purple.

Dichanthelium leucoblepharis (Trin.) Gould & Clark var. *leucoblepharis (Panicum ciliatum* Ell.) is found on similar sites throughout the range of little panicum. Its spikelets, which are slightly larger than those of little panicum, are usually pubescent; those of little panicum are glabrous.

Little panicum is a frequent associate of pineland threeawn in the longleaf-slash pine-wiregrass type in Florida and Georgia.

Range: Coastal Plain, Louisiana to Florida and Southern Georgia.

Perennial (spring phase). **Culms** tufted, 15 – 45 cm tall, usually erect; **leaves** mostly basal, **blades** 3 – 6 cm long, 4 – 6 mm wide, ciliate; **cauline leaves** few, reduced in size; **panicle** 3 – 4 cm long, about as wide, axis pilose; **spikelets** 1.2 – 1.8 mm long, glabrous, obovate.



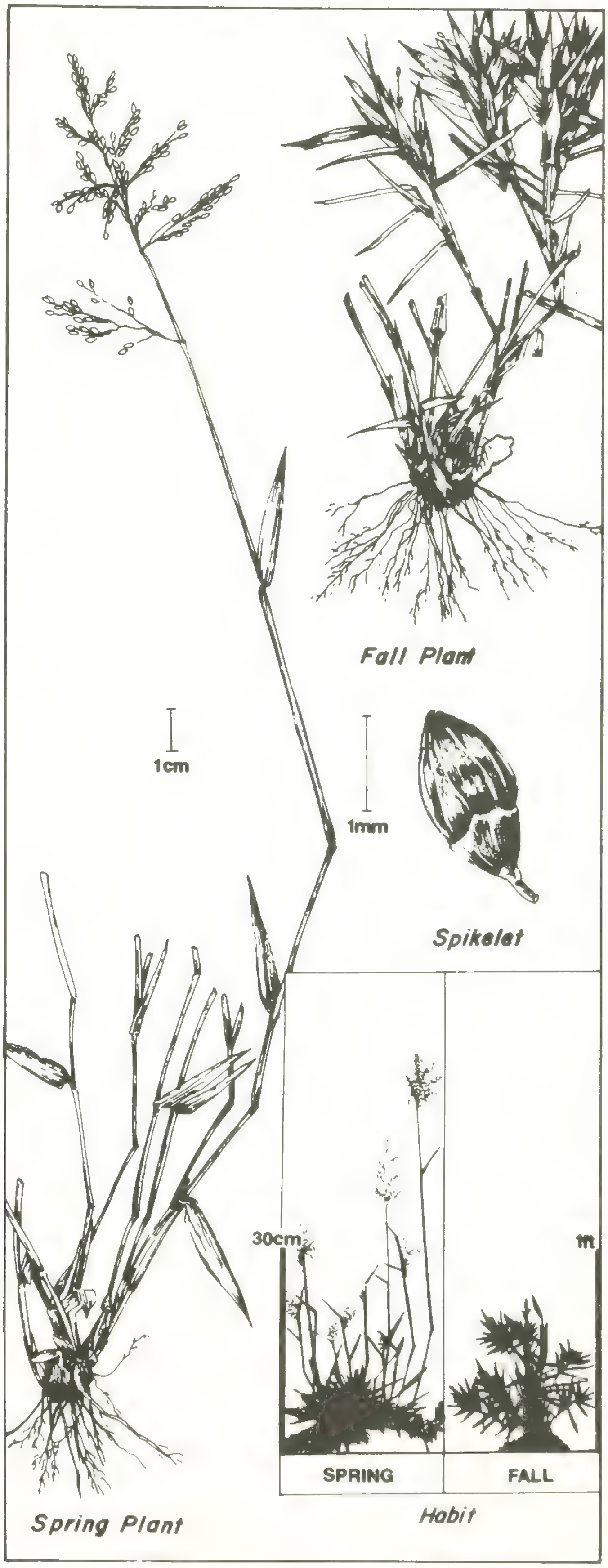
Lance Panicum—*Dichanthelium sabulorum* var. *patulum* (Scribn. & Merrill) Gould & Clark—(*Panicum lancearium* Trin.)

This low panicum is found in low, moist, sandy woods of the Coastal Plain, primarily in the pine flatwoods of the longleaf-slash pine-wiregrass type. Spring clumps have numerous erect purplish stalks about 1 foot tall, the outer bent upward at the lower joints. Leaves as well as stems may turn purple as spring foliage matures. Although plants appear hairless to the naked eye, stems and leaves are sparsely coated with short gray hairs.

Spring leaf blades are 1 to 2 inches long. Panicles are about 2 inches long and about as wide, with fine wavy branches and spikelets about ⅛ inch long. Fall foliage branches are less than 6 inches long with closely spaced blades about 1 inch long. As in most low panicums, fall seeds are on reduced axillary panicles, partially hidden by leaves.

Range: Coastal Plain, Texas to Florida and Massachusetts.

Perennial (spring phase). **Culms** 20 – 50 cm tall, puberulent, cespitose, branching from base only, erect, outer stems decumbent at base; **blades** 2 – 6 cm long, 3 – 7 mm wide, glabrous on upper surface, puberulent below; **panicle** 3 – 6 cm long, 2.5 – 5.0 cm broad; **spikelets** 1.8 – 3.6 mm long, puberulent or occasionally glabrous.



Roundseed Panicum—*Dichanthelium sphaerocarpon* (Ell.) Gould var. *sphaerocarpon*—(*Panicum sphaerocarpon* Ell.)

Although roundseed panicum has the seasonal vegetational variations of the low panicums, its fall and spring phases do not differ drastically. Thus, fall leaves are not greatly reduced or crowded, and fall panicles are fully exserted above the leaves. The short, broad leaves of the winter rosette are conspicuous.

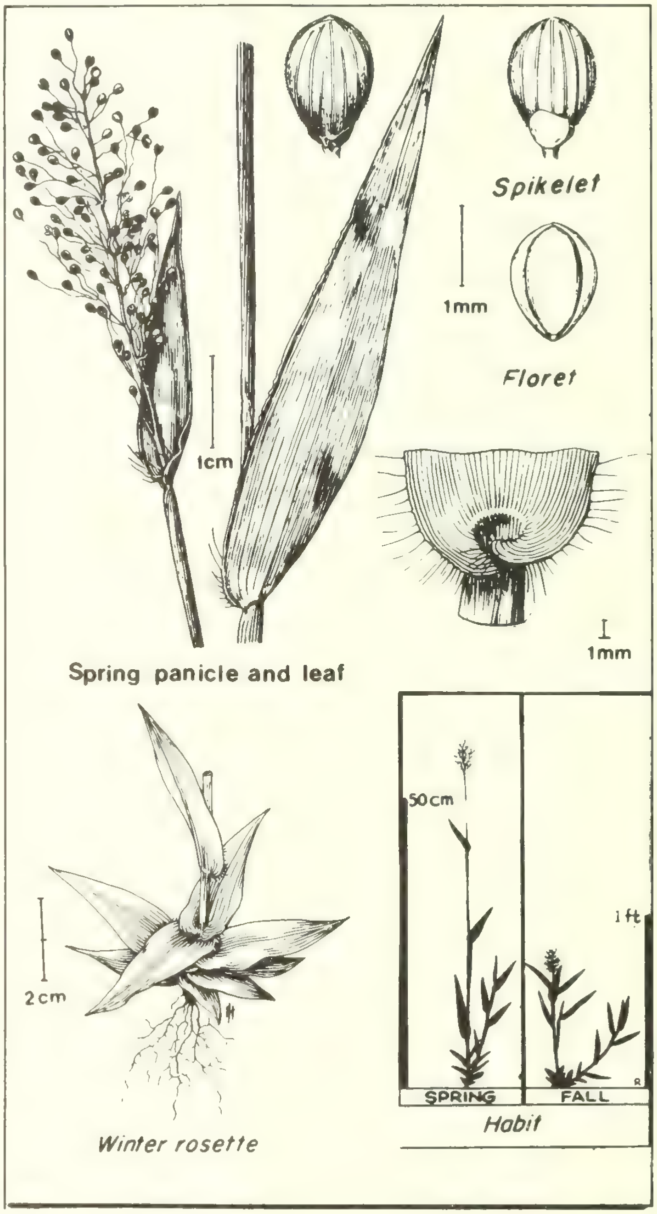
This panicum is widely distributed through the piney woods in the Southeast, in association with the bluestems. In the northern states, it grows on sandy woodland soils. Like other low panicums, it yields little forage, but quality is good.

Roundseed panicum is distinctive because of its relatively broad leaves and tiny spikelets. Spring leaves are mostly 2 to 4 inches long, lance shaped, and about ½ inch wide. Except for a few long white hairs at the leaf blade base, the plant appears almost hairless. Usually there is no ligule. When fully expanded, spring panicles are conical and 2 to 4 inches long. Spikelets are generally purple and about $^{1}/_{16}$ inch long.

A variety, *Dichanthelium sphaerocarpon* var. *isophyllum* (Scribn.) Gould & Clark, with larger leaves (to 10 inches long and 1¼ inches wide) and larger inflorescences (7 inches long and 3 inches wide), grows throughout most of the range of typical roundseed panicum.

Range: Practically the entire eastern half of the United States from Texas and northern Florida to Kansas, Michigan, and Vermont; also reported from Mexico to Venezuela.

Perennial (spring phase). **Culms** 20 – 80 cm tall, spreading, sometimes nearly erect, the nodes appressed-pubescent; **sheaths**, the upper shorter, the lower longer than the internodes, ciliate on the margin, sometimes with viscid tubercles between the nerves; **ligule** obsolete or nearly so; **mid-culm blades** 5 – 10 cm long, 6 – 11 mm wide, the lowermost and uppermost shorter, thick, firm, acuminate, slightly narrowed to a subcordate base, margins cartilaginous and stiffly ciliate, often papillose; **inflorescence** a long-exserted panicle 5 – 10 cm long, nearly as wide, the axis and ascending branches with viscid spots; **spikelets** 1.4 – 2.2 mm long, dark purple, green, or white, puberulent; **first glume** about one-fourth the length of the spikelet; **second glume** and **sterile lemma** equaling the fruit at maturity, 5- to 7-nerved.



Spreading Panicum—*Panicum anceps* var. *rhizomatum* (Hitchc. & Chase) Fern.

Although some recent authors (Gould 1975, Allen 1980, Correll and Johnston 1970) consider spreading panicum only a Coastal Plain variant of beaked panicum, *Panicum anceps* Michx., others (Radford and others 1968, USDA 1982) recognize them as separate varieties. The criteria used to separate the two are:

Variety	*Panicle*	*Spikelet size*	*Rhizome*	*Range*
anceps	open	2.5 – 3.8 mm	short	throughout SE U.S.
rhizomatum	more or less contracted	<2.2 – 2.8 mm	elongate	Coastal Plain

The varietal difference is probably valid, especially when inland specimens from Missouri are compared with plants from the lower Coastal Plain of Louisiana. However, both types can be lumped under *P. anceps* without fear of error.

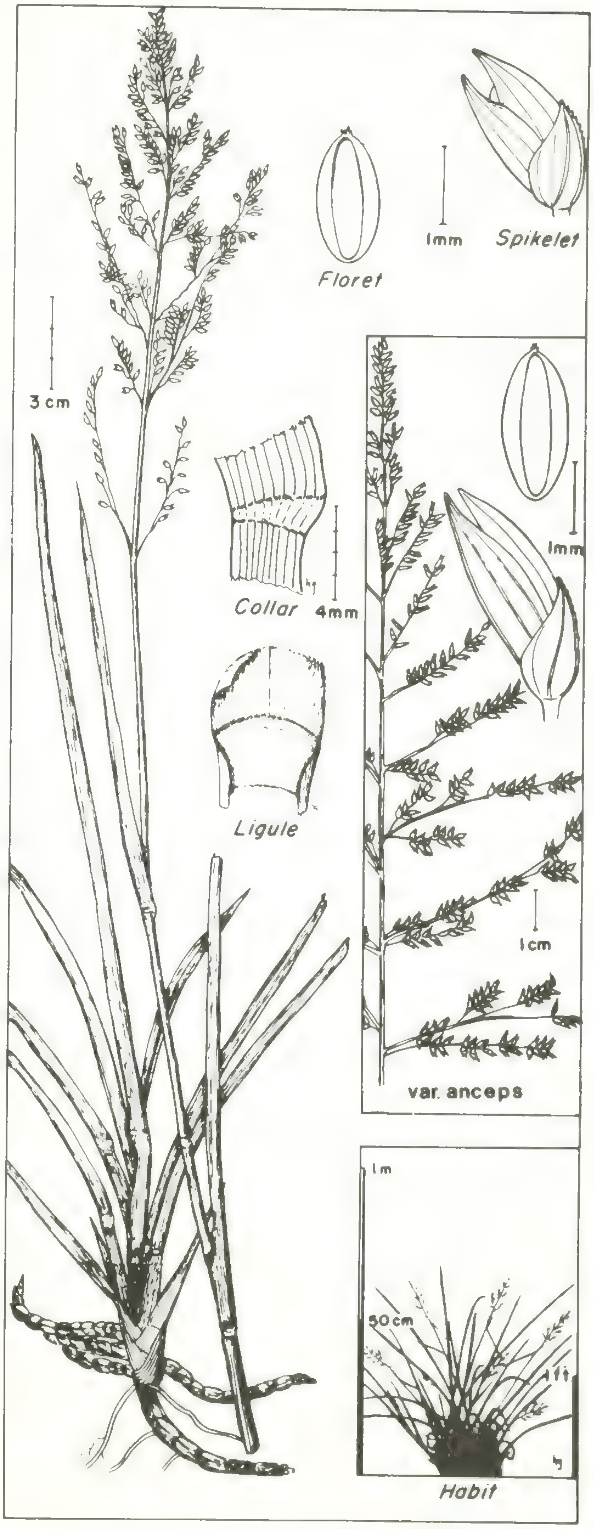
Gaping panicum grows on the same sites as spreading panicum. Although the two are similar, spikelets of spreading panicum sit obliquely on pedicel tips, while those of gaping panicum sit straight with the pedicel axis. Gaping panicum has no rhizomes.

Spreading panicum grows on wet sites throughout pine forests of the lower Coastal Plain. It commonly inhabits poorly drained flats, shallow depressions, drainageways, and stump holes on open sites or under moderate pine canopies.

Like other true panicums, it lacks distinct seasonal phases and flowers only once a year. Seedstalks are generally less than 3 feet tall, from long, slender rhizomes. Basal leaves are usually numerous; the blades measure about ½ inch wide and a foot or more in length. Close grazing causes basal tufts to spread widely, the prostrate leaves forming a dense cover over small areas.

Spreading panicum is readily eaten by cattle. Even on moderately grazed range, plants usually are closely utilized. The species withstands heavy use, but is rarely abundant except on small areas, and hence contributes only small quantities of forage.

Range: Coastal Plain, Texas to Florida, extending north to Maryland, inland to Tennessee.



Perennial. **Culms** 50 – 100 cm tall, compressed, from slender, scaly rhizomes; **sheaths** crowded at the base, glabrous to densely papillose-villous, particularly villous at the collar; **ligule** short, almost obsolete, with a dense area of hairs above it; **blades** 10 – 40 cm long, erect or spreading, 5 – 10 mm wide, glabrous to villous on both surfaces; **inflorescence** a terminal panicle 10 – 25 cm long, somewhat contracted and densely flowered; **spikelets** 2.2 – 2.8 mm long, obliquely set on their appressed, scabrous pedicels; **first glume** one-third to one-half as long as the lemma, with a prominent scabrous keel; **second glume** and **sterile lemma** subequal, slightly beaked; **floret** about 1.9 mm long, ovoid, pale and shining, tipped with a group of minute, thick hairs.

Maidencane—*Panicum hemitomon* Schult.

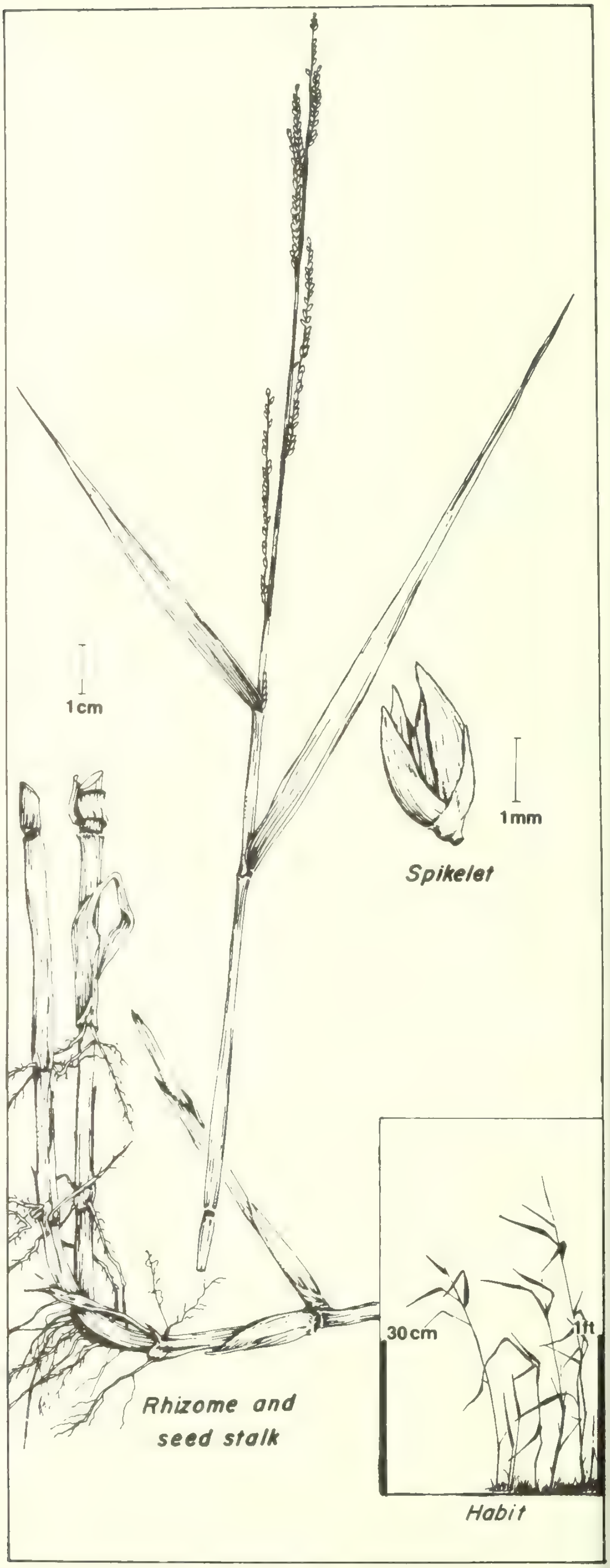
Maidencane or “paille fine” as it is called in Louisiana and east Texas, is a warm-season perennial grass important on freshwater marshes and open, wet sites in the Coastal Plain. It spreads by underground runners and may occur in extensive, almost pure stands. Stems, some sterile, some producing seed heads, are 20 to 60 inches tall. Sterile stems, which produce no seed heads, have hairy leaf sheaths; stems producing seeds are hairless.

When not killed by frost, maidencane produces high quality forage yearlong. In Louisiana marshes, earthen walkways are often constructed to allow cattle easier access to the wet sites occupied by this grass. Periods of high water during summer months provide marsh ranges a natural grazing deferment. Overgrazing can be very detrimental to maidencane, especially if sites are abnormally dry.

Maidencane yields 4 to 5 tons per acre of high quality herbage. When cut in the young growth stage, it makes excellent hay. Mature herbage, though tougher and less palatable than spring growth, may contain over 9 percent protein.

Range: Coastal Plain, Texas to Florida, extending north to New Jersey; reportedly collected also in Tennessee.

Perennial. **Culms** rhizomatous, sterile stalks with densely hirsute sheaths, fertile stalks 50 – 150 cm tall with glabrous sheaths; **blades** 10 – 25 cm long, 5 – 15 mm wide, glabrous; **panicle** 15 – 30 cm long, branches appressed, 2 – 10 cm long; **spikelets** 2.4 – 2.7 mm long, lanceolate; **first glume** about half the length of spikelet, acute.



Torpedograss—*Panicum repens* L.

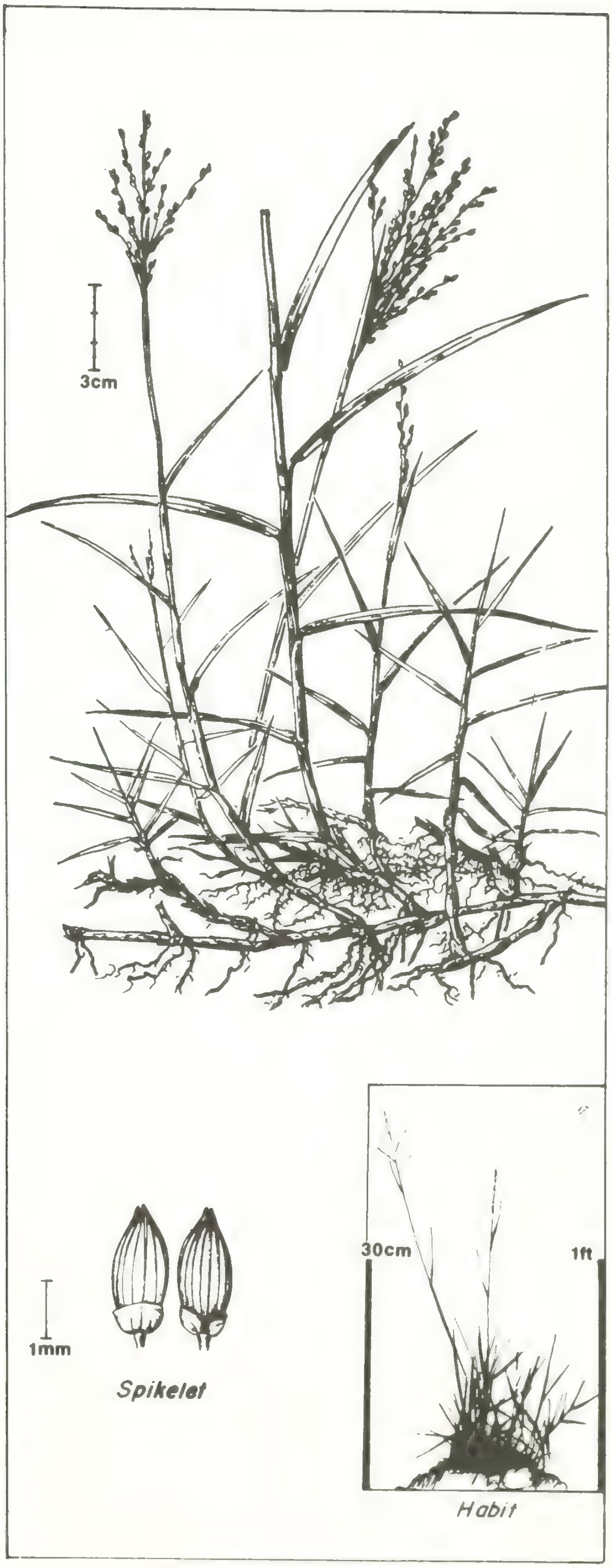
Torpedograss is a familiar grass on gulf coastal beaches, where it is a major natural factor in stabilizing sand dunes. Rigid stalks 1 to 4 feet tall rise from the nodes of extensively creeping rootstocks, which also may root at the nodes. Seed heads are open, 3 to 5 inches long, with ascending branches. The common name was derived from the sharp-pointed rhizomes. Torpedograss grows inland on ditch and canal banks, often extending into the water. It invades cultivated cropland on moist fertile sites and thrives as a pasture plant.

Foliage is gray-green to blue-green and practically hairless. Leaves are palatable to cattle and nutritious. Although foliage is easily killed by frost, dry grass in winter retains a relatively high nutrient content.

Torpedograss is a member of the true panicum group, and is closely related to switchgrass. The stout, sharp-pointed rhizomes, however, distinguish torpedograss from any other similar grass.

Range: Gulf coast, Texas to Florida.

Perennial: **Culms** erect, rigid, 30 – 100 cm tall from extensively creeping horizontal rootstocks; **rootstocks** with bladeless sheaths from nodes; **sheaths** (culm) more or less pilose; **blades** flat or folded, 2 – 5 mm wide, linear-lanceolate, sparsely pilose to glabrous; **ligule** membranaceous, ciliate; **panicle** open, 7 – 12 cm long, branches somewhat distant, stiffly ascending; **spikelets** 2.2 – 2.5 mm long, ovate, pale, turgid, strongly 5- to 9-nerved, glabrous, pointed; **first glume** truncate, about one-fifth as long as the spikelet.



Bluejoint Panicum—*Panicum tenerum* Beyr.

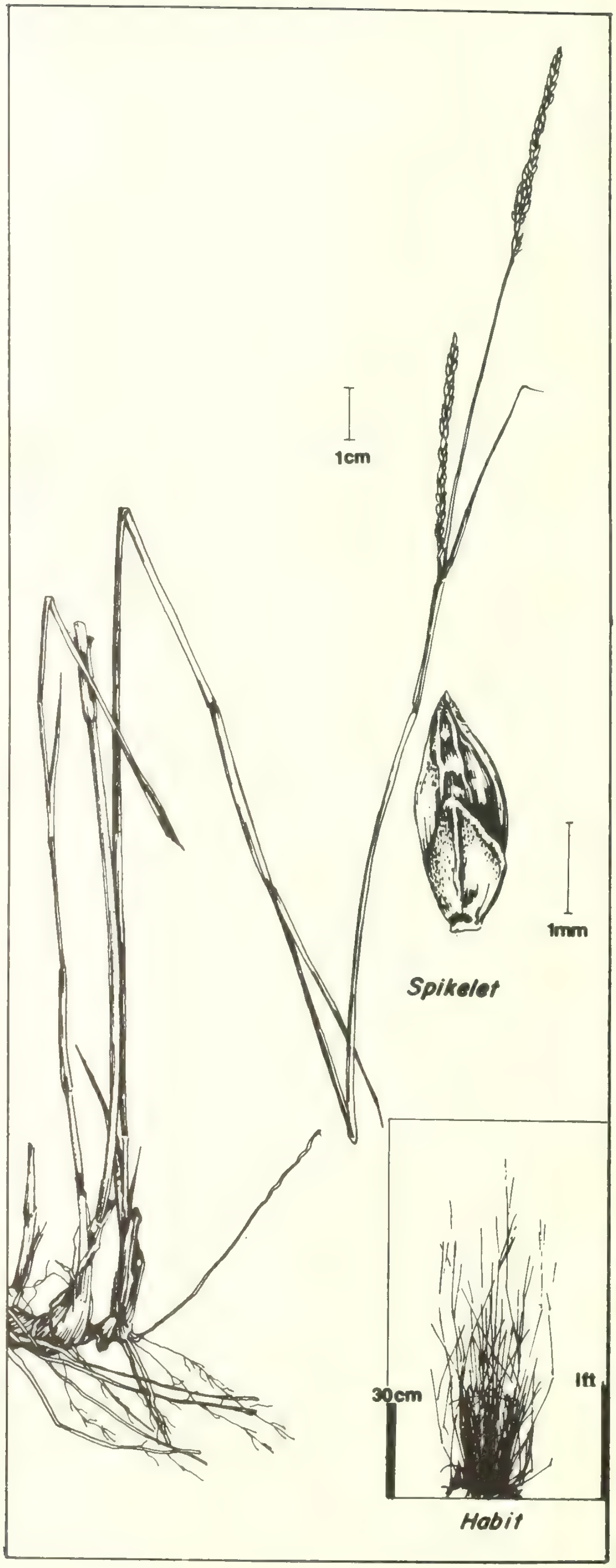
Bluejoint panicum is a wiry perennial bunch grass of the true panicum group, with erect stems about 2 feet tall arising from a knotted crown. Foliage is hairless, and the nodes, or joints, are smooth and blue or purple in color, giving plants a distinctive "bluejoint" appearance. The plant grows on a variety of wet sites along the gulf and Atlantic coasts.

Cattle graze bluejoint panicum in the spring before foliage matures. Regrowth following a spring burn is palatable, but by late summer even burned herbage is tough and wiry. On slough sites in good condition, it may contribute up to 35 percent by weight of the total herbage.

Flower stalks are produced from June through August. The inflorescence consists of one to several ascending branches about 3 inches long, with small, crowded spikelets. Branches, which may be terminal or axillary or both, are often only slightly exserted from leaf sheaths. Appearance of the inflorescence, along with the wiry leaves and stems, may lead to confusion with some of the dropseeds *(Sporobolus* spp.). Bluejoint panicum, however, has a typical true panicum spikelet; the first glume is about half the length of the spikelet, with a strongly nerved and pointed second glume and sterile lemma.

Range: Near the coast, Texas to Florida and North Carolina.

Perennial. **Culms** wiry, in small tufts from a knotted crown 40 – 90 cm tall; **nodes** glabrous, purple or bluish; **lower sheaths** pubescent with spreading hairs toward summit; **blades** 4 – 15 cm long, 2 – 4 mm wide, ascending or erect, sub-involute, pilose on the upper surface toward base, glabrous beneath; **panicles** 3 – 8 cm long, 0.5 – 1.0 cm wide, very slender, terminal and axillary, branches ascending to appressed; **spikelets** 2.2 – 2.8 mm long, pointed, glabrous; **fruit**, brownish, shiny.



Warty Panicum—*Panicum verrucosum* Muhl.

This annual of the true panicum group is a sprawling grass with culms up to 5 feet long branching and rooting at the nodes. It inhabits moist sandy sites and is most abundant in the understory of open woods. Foliage is lax, hairless, and light green with white midribs in the blades and white veins in the sheaths. Basal joints are bent and the lower joints of the stem are purple. The upper stem is hidden by the sheaths. Blades are 2 to 8 inches long and 1/5 to 2/5 inch wide.

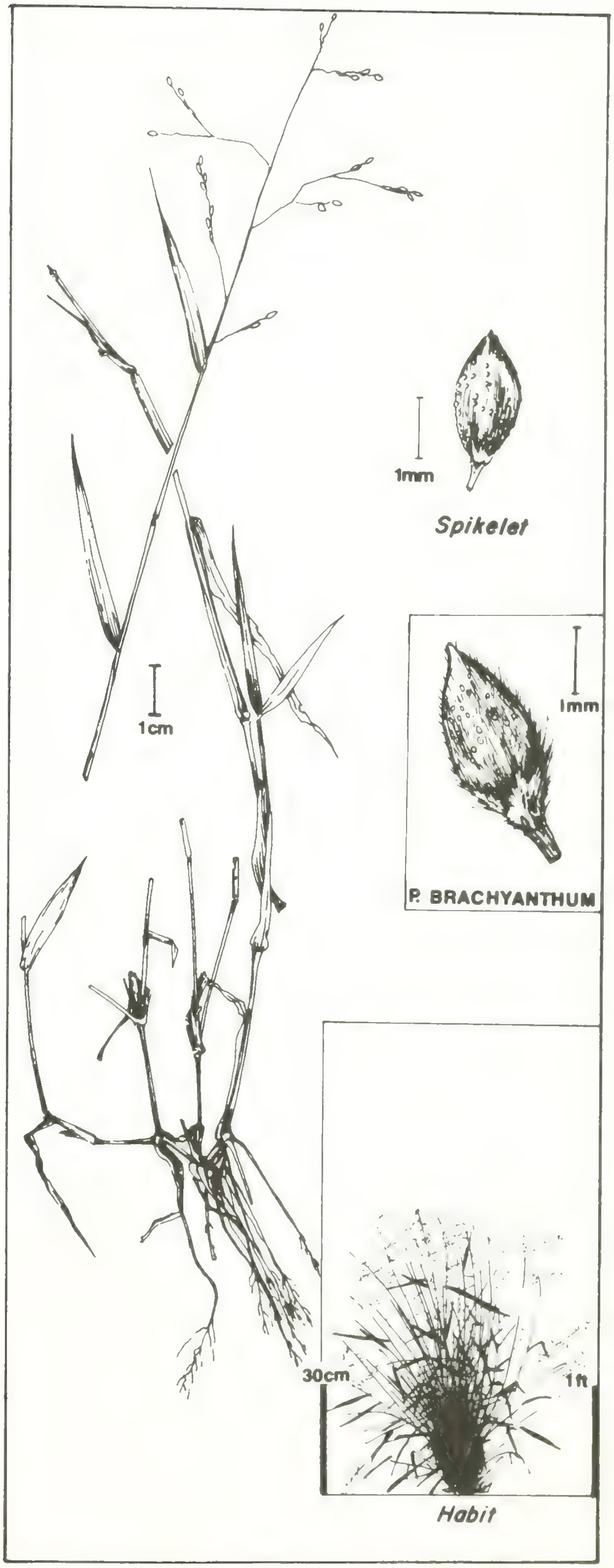
The panicle is 2 to 12 inches long with numerous ascending branches. Spikelets, borne on short appressed branchlets on the outer half of the main branches, are about 1/16 inch long and green. The outer bracts are covered with small tubercles, giving spikelets a "warty" appearance.

Seeds of warty panicum usually germinate by March, and plants are tall enough to furnish some grazing by May. The grass provides excellent forage through September. Seeds are eaten by quail and other birds.

Before seedheads form, warty panicum may be confused with crabgrasses, *Digitaria* spp., which have a similar sprawling growth habit. A close relative, pimple panicum, *Panicum brachyanthum* Steud., occurs in sandy sites in Texas, Oklahoma, Arkansas, and Louisiana. It is also an annual, but wiry, with very narrow leaves, and is practically worthless as forage. Pimple panicum has fewer branches, and spikelets are hairy as well as warty.

Range: Texas and Arkansas to Florida, Michigan, and Massachusetts.

Annual. **Culms** to 150 cm long, nodes glabrous and purple, hidden by sheaths except near base, lower stems decumbent, rooting at nodes; **foliage** lax, light green, glabrous; **sheaths** with white veins; **blades** 5 – 20 cm long, 4 – 10 mm wide, with white midrib; **panicles** 5 – 30 cm long, about as wide, with ascending compound branches; **spikelets** few (usually two) at tip of branches and branchlets; 1.8 – 2.1 mm long, elliptic-obovate, tuberculate.



Switchgrass—*Panicum virgatum* L.

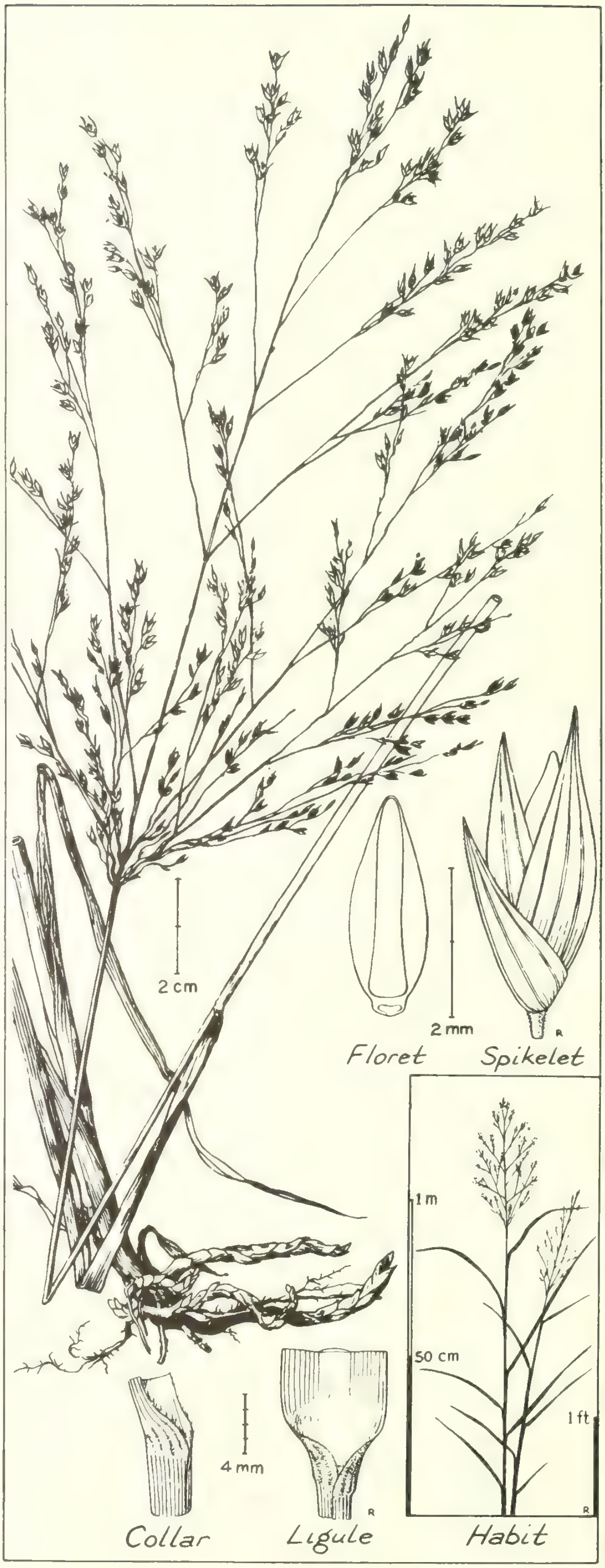
Switchgrass is one of the true panicums, having no seasonal phases and flowering only in late summer or early fall. It is among the tallest panicums in the South, averaging 3 to 4 feet tall on forest range, but reaching 6 to 7 feet on favorable sites. Switchgrass is highly variable, however, and small, fine-stemmed specimens may be encountered.

Because plants spread by numerous scaly rhizomes, switchgrass often forms large, dense colonies. It is usually sparse on well-drained range sites, but on moderately wet sandy soils it may be the dominant grass. Tolerance of shade renders this grass potentially important for grazing under young pines and in stands that have been thinned several times. Before foliage matures, cattle prefer it to most associated species. Where it comprises a minor part of the forage, therefore, it is overgrazed. Switchgrass also has value for wildlife. Birds eat the seeds, and deer reportedly paw up and eat the rhizomes when winter food is scarce.

Plants are generally hairless except for dense white hairs behind the ligules and scattered hairs on the bases of leaf blades. The inflorescence is an open panicle ½ to 1½ feet long with ascending branches. Dried panicles persist on stiff, stout flower stalks through the winter and well into the next growing season, providing a reliable guide to identification. Spikelets are up to $^{3}/_{16}$ inch long, among the largest in southern panicums.

Beaked panicum and spreading panicum, though similar in form, are usually smaller throughout. These are distinguishable from other panicums by the gleaming white midribs of their leaf blades and satiny sheath linings. While foliage of switchgrass resembles that of yellow indiangrass, the latter can be identified by prominent auricles at its leaf collars.

Range: Throughout the United States except Idaho, Montana, and the Pacific States.



Perennial. **Culms** 1 – 2 m tall, terete, robust, erect, solitary or in clumps from long, hard, scaly rhizomes; **sheaths** green to purple tinged, often glaucous, gleaming white within, mostly glabrous, though sometimes pilose; **ligule** membranous-ciliate, a pale tan to brown membrane 1 – 2 mm long with a dense mass of fine, white hairs on the back and arising from it, 3 – 7 mm long, the membrane sloughing off with age to leave a dense ring of hairs; **blades** 3 – 15 mm wide, often glaucous, 10 – 60 cm long, with a prominent, wide, white midrib, ascending, taper-pointed, mostly glabrous but sometimes pubescent to pilose on both surfaces, margins scabrous; **inflorescence** a long-exserted open panicle 15 – 50 cm long with ascending branches; **spikelets** 3.5 – 5.0 mm long, ovoid, acuminate, with prominent nerves; **first glume** shorter, **second glume** longer than the **sterile lemma**; **floret** narrowly ovoid, 2.6 – 3.8 mm long or about three-fourths the length of the spikelet.

Gaping Panicum—*Steinchisma hians* (Ell.) Nash—(*Panicum hians* Ell.)

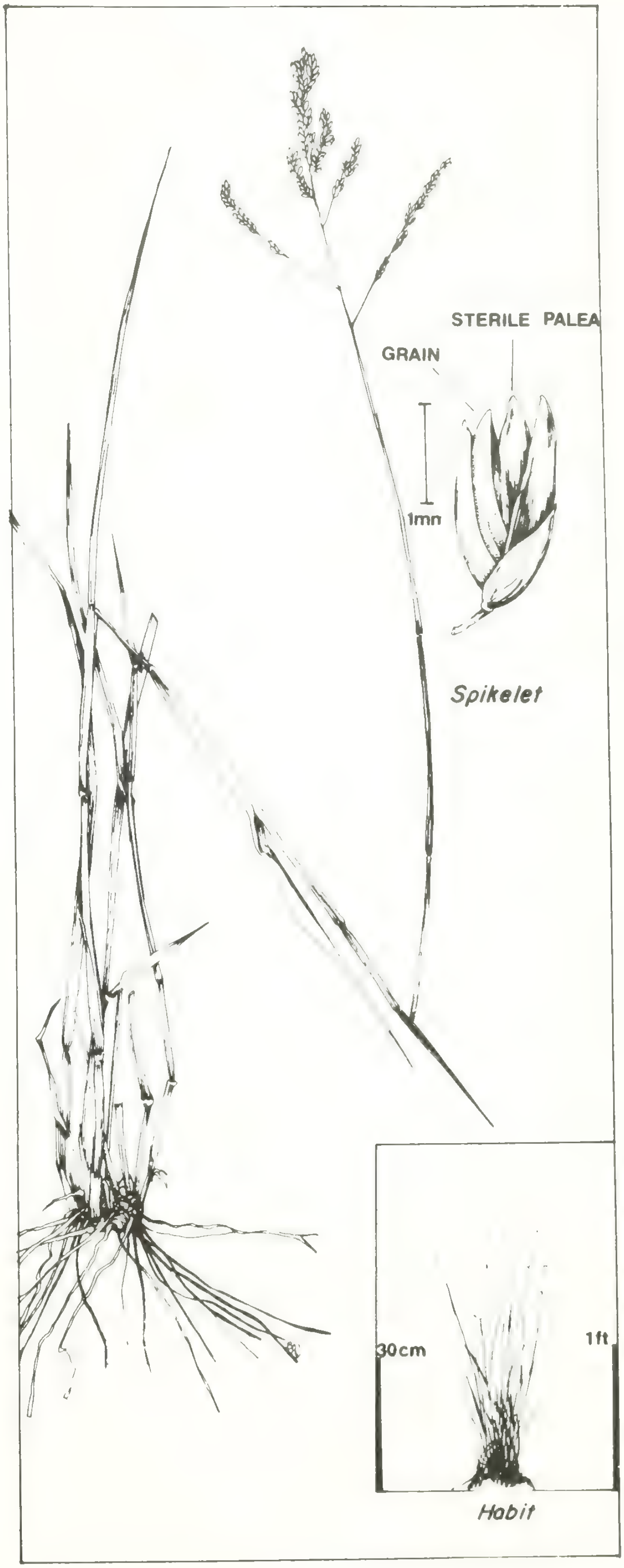
An old name, *Steinchisma hians,* was restored as the preferred synonym in the "National List of Scientific Plant Names" (USDA 1982). No new common name was proposed, however, so the grass will probably continue to be known as gaping panicum. In this handbook it is included with the true panicums.

Gaping panicum grows to 2 feet tall in ditches, stumpholes, on pond or stream margins, and other moist sites. It is a common grass on such sites from the desert southwest to the Atlantic coast, but seldom grows in abundance. Flowering begins in late spring and many plants mature seed by mid-summer. Forage value is considered only fair, although new growth in spring or following fire is grazed readily by cattle.

Gaping panicum leaves are 2 to 6 inches long and less than ¼ inch wide. Growth form varies from upright clumps of erect, narrow leaves to sprawling or prostrate plants with relatively broad, lax blades. The inflorescence is an open panicle, with few widely spaced branches. Small short-stalked spikelets are crowded on the outer half of each branch. The inflorescence resembles that of longleaf wedgescale, *Sphenopholis filiformis* (Chapm.) Scribn., a common grass on dry sites throughout the Southern states. The spikelet of gaping panicum is unique; a sterile bract (palea) is inflated and hardened, appearing almost as a second grain.

Range: New Mexico and Missouri to Florida and Virginia.

Perennial. **Culms** 20 – 60 cm tall, erect or sometimes decumbent or prostrate; **sheaths** shorter than internodes, ciliate or pilose near collar; blades 5 – 15 cm long, pilose to glabrous, about 6 mm wide; **panicle** loose and open, 5 – 20 cm long, primary branches few, ascending to drooping; **spikelets** glabrous, 2.2 – 2.4 mm long, about as wide and thick as long at maturity, falling entire; **sterile palea** inflated, indurate at maturity; **grain** about 1.5 mm long.



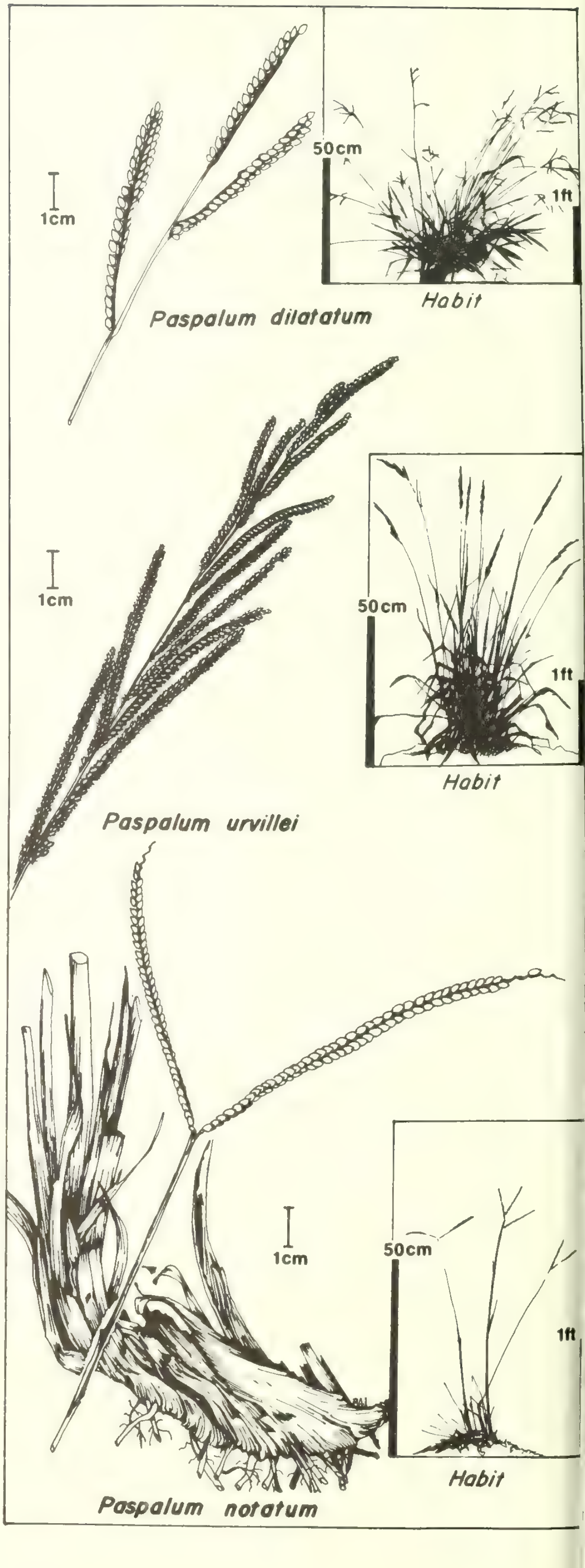
Paspalum Grasses—*(Paspalum* spp.)

The paspalums constitute the second largest group of grasses in the southeastern United States, with approximately 50 species. Many have ranges extending into Mexico, Central and South America, and the Caribbean Islands. Included are several species introduced from South America into the southern United States as pasture grasses. Vaseygrass, *Paspalum urvillei* Steud., dallisgrass, *P. dilatatum* Poir., and bahiagrass, *P. notatum* Fluegge, are notable examples. The latter two species can be troublesome weeds in lawns across the South.

Paspalums occur on a variety of sites. Species on upland range usually grow as scattered clumps or individual plants and do not produce abundant forage. New growth is palatable and relatively high in nutrients, but plants mature early, and the mature foliage weathers rapidly. Paspalums are most abundant and robust where plant competition is light, as on firelines and roadsides.

The paspalum inflorescence usually consists of one to several racemes, each with spikelets in rows along the lower side. In prevalent native species, only one raceme originates from a given point on the main axis. These often extend in a common direction, making the inflorescence one sided. Grains are flat on one side, convex on the other.

Flowers of several paspalums are often infected by ergot, produced by a fungus *(Claviceps paspali* F. S. Stevens and J. G. Hall) that attacks and destroys the immature grain. Other fungi sometimes grow on the "honeydew" exuded by the ergot and produce a variety of colors in the seed heads. Although ergot is toxic to cattle, danger of ergot poisoning is slight on properly managed ranges, as paspalums usually comprise a small part of the diet.



Florida Paspalum—*Paspalum floridanum* Michx. var. *floridanum*

Florida paspalum is one of the most robust grasses on southern pine ranges. It averages 3 feet tall, but some plants may reach 6 feet or more. Leaves, which are mostly basal, ascend stiffly. Blades are up to 20 inches long and ⅜ inch wide. The dark green foliage is usually densely hairy, but occasional specimens are almost hairless. Each stalk has two to five thick racemes, each about 3 inches long.

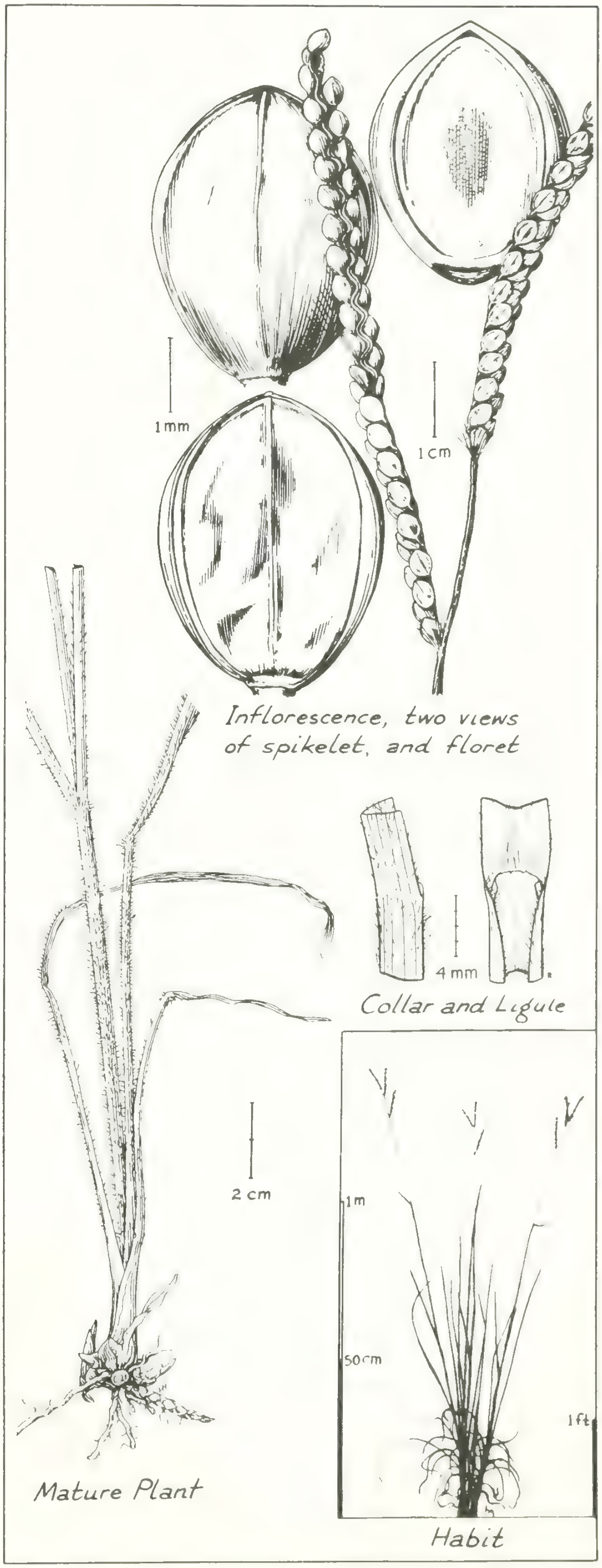
This grass thrives on disturbed sites such as firelines, road ditches, and stump holes. On undisturbed range, it prefers moist, well-drained soils, but also grows on dry sandy sites and poorly drained flats. Under light competition, plants spread by stout, scaly rhizomes to form large, loose bunches; in dense bluestem stands clumps are small.

Florida paspalum is readily distinguishable from other paspalums on longleaf pine ranges by its robust habit, large spikelets, and long, broad leaves. Until inflorescences appear in early summer, the species may be confused with big bluestem. Thereafter, and where old seedstalks persist, Florida paspalum can be distinguished by the conspicuously zigzag rachises of the shattered racemes. Vegetative differences are described under big bluestem. An even more robust form with hairless, chalky foliage, *Paspalum floridanum* var. *glabratum* Engelm. ex Vasey, is commonly found in brackish marshes along the Atlantic and gulf coasts and may be found as a weed on wet sandy sites throughout the range of typical Florida paspalum.

The young leaves are palatable and nutritious. As plants mature, the foliage becomes tough and less palatable. The grain, which is among the largest of southern range grasses, is eaten by quail, doves, and turkey.

Range: Texas to Florida, extending north to Missouri and Maryland.

Perennial. **Culms** 1 – 2 m tall, solitary or sparse from robust, scaly rhizomes; **sheaths** keeled, overlapping below, glabrous to villous, sometimes papillose; **ligule** a firm brown membrane 2 – 3 mm long; **blades** 15 – 50 cm long, 4 – 10 mm wide, usually villous on the upper surface near the base, ascending, firm, flat or folded, the upper ones reduced in size; **inflorescence** of two to five racemes 4 – 12 cm long; **spikelets** 4 mm long, crowded, ovoid, pale, and glabrous, usually in pairs, on each side of a zigzag rachis, but one sometimes absent or rudimentary; **first glume** wanting; **second glume** and **sterile lemma** equal, scarcely covering the fruit at maturity; **grain** 3.0 – 3.5 mm long, ovoid, light brown, minutely papillose, striate.



Inflorescence, two views of spikelet, and floret

Collar and Ligule

Mature Plant

Habit

Brownseed Paspalum—*Paspalum plicatulum* Michx.

Brownseed paspalum grows in forest openings and on cutover lands throughout the South. It invades where the soil has been disturbed and on areas that have been heavily grazed. Preferred sites include wet meadows, drainageways, and roadside ditches, where plants spread by rhizomes to form dense colonies. It is rare under well-stocked timber stands.

Plants produce several seedstalks from 1 to 3 feet tall. Each stalk bears several slender racemes 1 to 4 inches long. Spikelets are in two rows on the lower side of a flattened, zigzag axis. Grains are about ⅛ inch long, medium to dark brown, and shiny. In mature plants, grain color readily distinguishes brownseed paspalum from other paspalum grasses. Foliage is green to gray green or blue green. Leaves are firm to wiry, with blades up to 18 inches long.

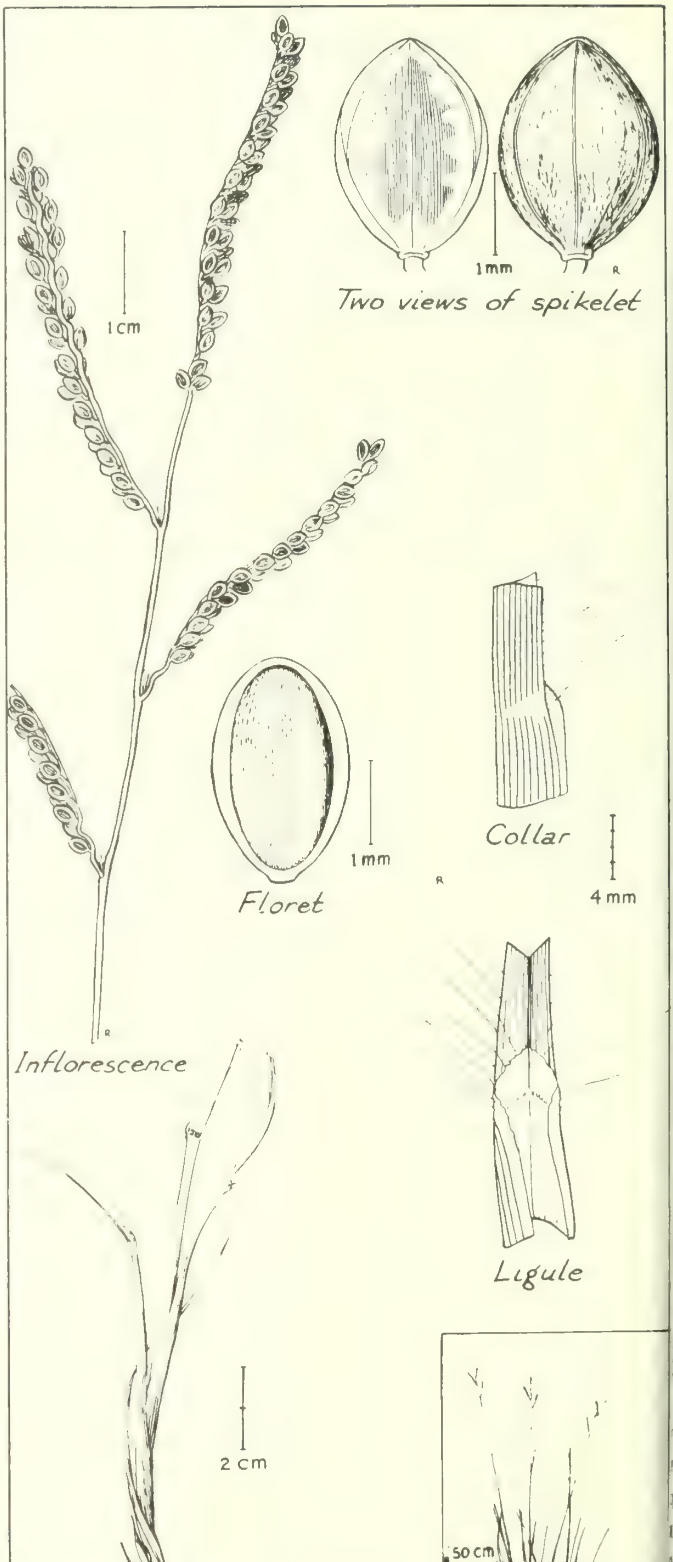
The common occurrence of brownseed paspalum along roadways and firebreaks within forests may exaggerate its abundance. Plants are sparse on most forest range sites, thus this species normally contributes only a minor part of the cattle diet. The foliage becomes tough and low in palatability by midseason, but because leaves frequently remain green through much of the winter, cattle may eat large amounts after frost kills back other grasses. In Florida, brownseed paspalum is one of the more palatable grasses.

Extensive stands should not be grazed when spikelets are heavily infected with ergot. Grazing may be resumed with little risk after seed heads shatter.

Birds eat the grain, but ergot makes the supply unreliable.

Range: Coastal Plain, Texas to Florida and Georgia.

Perennial. **Culms** 50 – 100 cm tall, in tufts with many leafy shoots, erect or ascending from a slightly decumbent base; **sheaths** keeled, the lower crowded, glabrous to papillose-pilose along margins and keel, or rarely hirsute throughout; **ligule** a pointed, pale-brown membrane 2 – 3 mm long; **blades** 8 – 45 cm long, 3 – 10 mm wide, basal ones folded, upper ones flat and usually greatly reduced in length, glabrous, but pilose at the base; **inflorescence** of three to eight racemes, each 3 – 10 cm long; **spikelets** 2.5 – 2.8 mm long, ovoid, brown at maturity; **first glume** wanting; the glabrous or appressed-pubescent **second glume** and transversely wrinkled **sterile lemma** equal, both thin and 5-nerved; **grain** 2.3 – 2.5 mm long, ovoid, brown, and shining.



Fringeleaf Paspalum—*Paspalum setaceum* var. *ciliatifolium* (Michx.) Vasey—(*Paspalum ciliatifolium* Michx.)

Fringeleaf paspalum, hurrahgrass, and barestem paspalum are closely related and intergrading species that were combined with a few other species under *Paspalum setaceum* Michx. (Banks 1966). Separate taxa were maintained by assigning them as varieties. Several recent plant manuals recognize only the species, thus lumping all the varieties (Radford and others 1968, Allen 1980). While separation may no longer be practical in forage management, the grasses are described as separate varieties in this book.

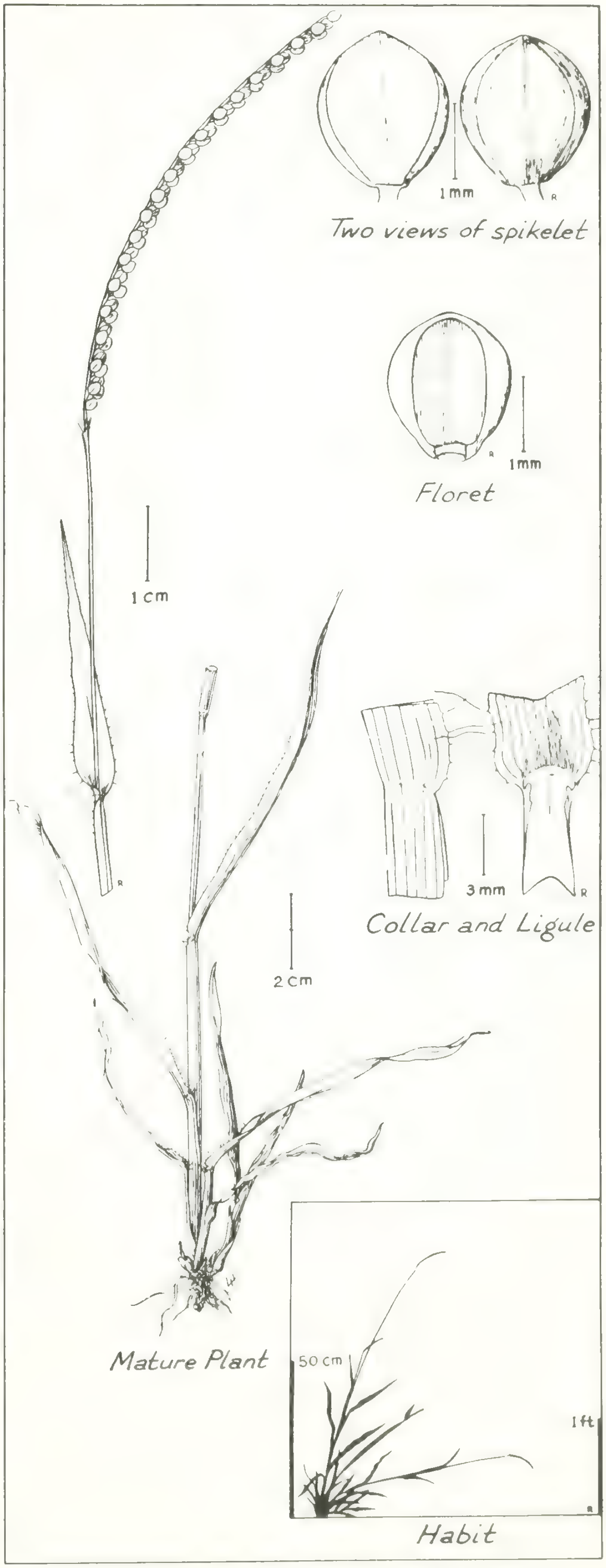
Fringeleaf paspalum is one of the smallest native paspalums. The slender flower stalks occasionally exceed 2 feet, but at this length they rarely stand erect. Leaves are mostly basal, often spreading along the ground. Light green blades, usually less than 8 inches long, are often twisted. The flower stalk ends in an inflorescence of one to three slender racemes, each 1½ to 4 inches long. In addition, there are axillary inflorescences, usually enclosed or half hidden in leaf sheaths. The grain is smooth, pale, and small—1/16 inch or less in length.

Growth habit and foliage of fringeleaf paspalum resemble those of some of the crabgrasses, *Digitaria* spp., which may inhabit the same site. Hairs are only on the margins of fringeleaf paspalum leaf blades; hairs of crabgrass blades, if present at all, grow from surfaces as well as margins. Through most of the growing season they can be distinguished by floral characteristics. Crabgrasses have only terminal racemes—generally three or more.

Fringeleaf paspalum grows almost exclusively on disturbed sandy sites. It is never abundant and hence not an important forage producer, even though palatable.

Range: Texas to Florida, extending north to Minnesota and New Jersey.

Perennial. **Culms** 20 – 90 cm tall, erect, or spreading from a knotted base, lower parts brown or purplish; **sheaths** keeled, glabrous, or the lower ones puberulent, glabrous, or ciliate along the overlapping margins; **ligule** membranous, short, backed by a ligular beard 1 – 3 mm long; **blades** ascending or spreading, 10 – 35 cm long, 7 – 12 mm or rarely 20 mm wide, usually strongly ciliate to ciliate-papillose along the undulate margin, otherwise glabrous, flat, acuminate at the apex, rounded to subcordate at the base; **inflorescence** of one to three terminal racemes, each 5 – 10 cm long, axillary raceme may be hidden in sheath; **spikelets** about 2 mm long, suborbicular; **first glume** wanting; **second glume** slightly shorter than the **sterile lemma**, exposing the fruit at maturity, second glume and sterile lemma both 3-nerved, the former glabrous to minutely pubescent with obscurely capitate hairs, sometimes minutely and dimly speckled; **grain** about the size and shape of the spikelet, pale yellow, smooth, and shining.



Barestem Paspalum—*Paspalum setaceum* var. *longepedunculatum* (LeConte) Wood—(*P. longepedunculatum* LeConte)

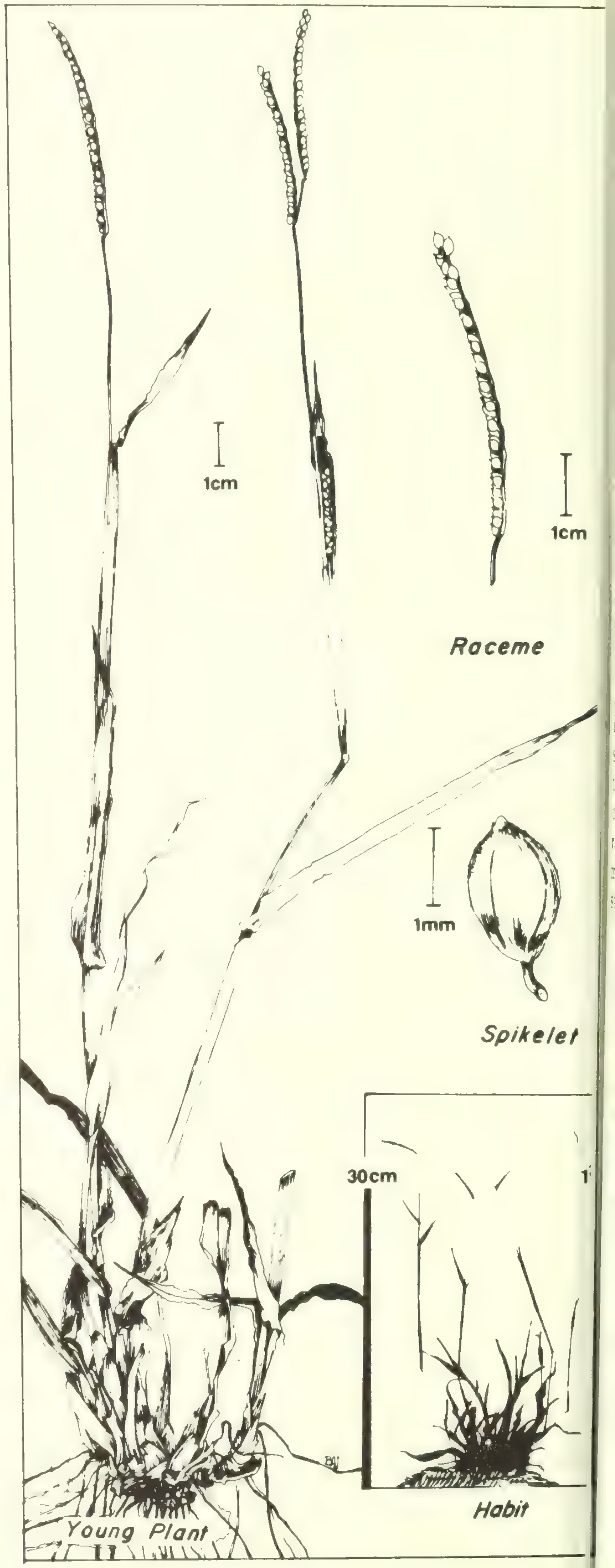
The common name for this grass was inspired by the long, slender, naked seedstalks (peduncles) which emerge from the upper leaf sheaths, supporting the terminal racemes as high as one foot above the uppermost leaf. A single stalk, terminated by one or two racemes, usually emerges fully, while others may be hidden in sheaths. Plants range in height from 8 inches to over 2 feet. It is found on low sandy pinelands throughout the South but is perhaps most common and important on the pine flatwoods of Georgia and Florida. As with most paspalums, however, plants are seldom found in abundance on undisturbed range. The largest number of plants are found on disturbed sites where plant competition has been reduced. Plants occur as clumps of a few to many stems arising from a knotty base, growing outward and bending upward at the lower joints.

Although forage value is considered only fair because of the limited quantity produced, seeds are eaten by quail and doves. Seeds mature by midsummer, and plants provide poor winter forage.

Fringeleaf paspalum is most likely to be mistaken for barestem paspalum; both have ciliate hairs on the margins of leaf blades, which are otherwise hairless. Spikelets of fringeleaf are larger and sometimes hairy; those of barestem are smooth. Leaf blades of barestem are 2 to 4 inches long and ⅛ to ⅝ inches wide; fringeleaf blades may be over 4 inches long. Other similar paspalums are generally hairy throughout. The slender racemes, small spikelets, and low foliage habit are also typical of some of the crabgrasses.

Range: Coastal Plain, Mississippi to Florida and North Carolina.

Perennial. **Culms** one to several from short rhizomes, ascending to erect, 20 – 80 cm tall, glabrous; **sheaths** ciliate on margin, purplish with age; **blades** ciliate on margins, 4 – 10 cm long, 3 – 8 mm wide; **ligule** a short, brown membrane with a ring of white hairs; **racemes** one to several, 3 – 8 cm long, terminating slender elongate peduncles, axillary raceme may be hidden in sheaths; **spikelets** glabrous, elliptic-obovate, 1.5 – 2.0 mm long, 1.0 – 1.2 mm wide.



Hurrahgrass—*Paspalum setaceum* var. *muhlenbergii* (Nash) Banks—*(Paspalum pubescens* Muhl.)

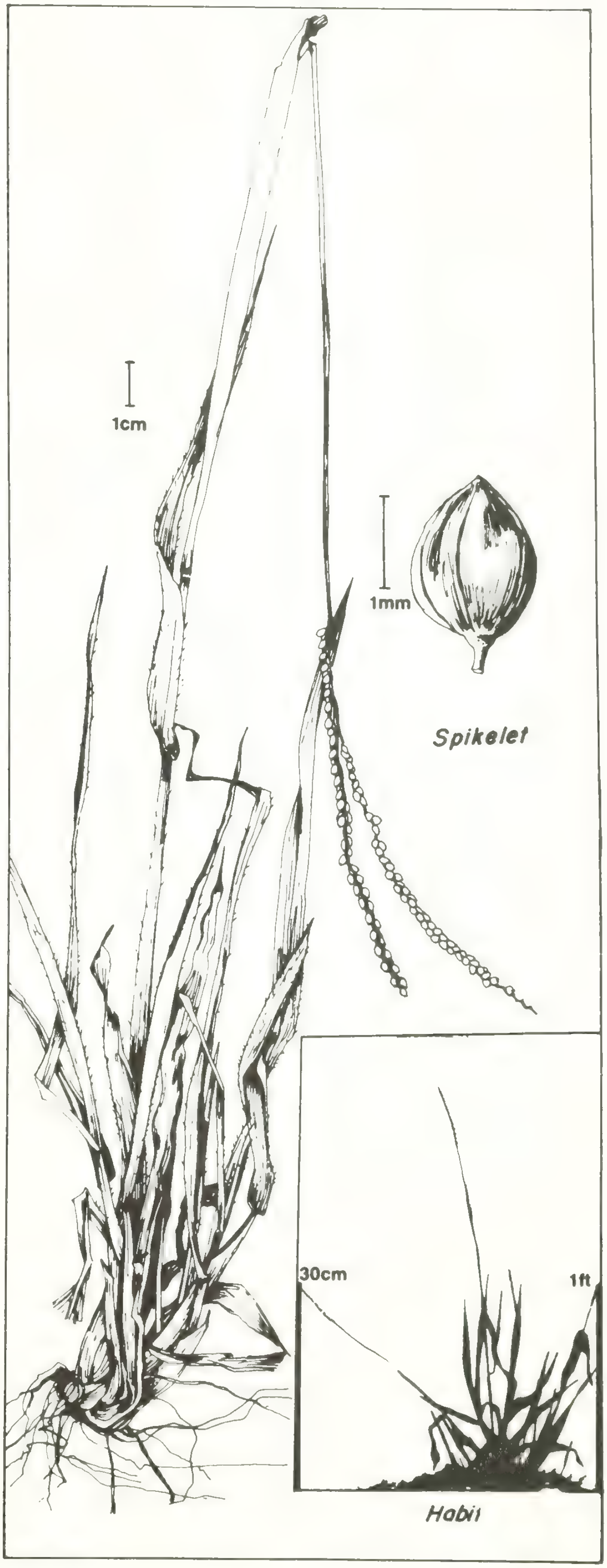
Hurrahgrass is a small paspalum grass frequently encountered throughout the South but seldom abundant. It is found most often on disturbed sandy sites growing as scattered individuals, sometimes in dense clumps. Flowering plants are about 2 feet tall, with ascending stalks. Foliage is usually covered with erect but soft hairs, but some plants are almost completely hairless.

As in other varieties of *Paspalum setaceum*, racemes are slender and usually about 2½ to 3 inches long. Each stalk is terminated by a single raceme, although there may be one or two hidden below. Flowering branches also may emerge from the upper sheaths. Spikelets are hairless, almost round and about 1/16 inch long. Seed are eaten by birds, but the plant is not abundant enough to be considered a major wildlife food plant.

Fringeleaf paspalum and barestem paspalum have approximately the same range as hurrahgrass and occur on similar sites. Leaf blades of both are essentially hairless, however, and spikelets are slightly smaller than those of hurrahgrass.

Range: Texas and Kansas, extending to Florida, Michigan, and Vermont.

Perennial. **Culms** ascending, branching at base, from short rhizomes, 45 – 90 cm tall; **sheaths** usually pilose toward summit, occasionally glabrous; **blades** 8 – 20 cm long, 2 – 10 mm wide, pilose on both surfaces; **racemes** one to three terminal, 4 – 17 cm long, one or more hidden in sheath; **spikelets** about 2 mm long, suborbicular, usually glabrous.



Miscellaneous Grasses

Although the bluestems, panicums, and paspalums account for most grass forage on southern pine forest range, many other grass genera are represented, often by a single species. Few are important forage plants. Some are grazed only when other forage is unavailable; others, though readily eaten by cattle, either are widely scattered individuals or grow abundantly only on certain sites.

Goobergrass—*Amphicarpum muhlenbergianum* (Schult.) Hitchc.

Goobergrass, known also as blue maidencane, is a warm-season perennial grass found on wet sites, such as low pine forests and pond or marsh shores. Its range is limited to the Coastal Plain of the four southeasternmost states. Spikelets produced in the terminal panicle are perfect but do not produce seed. Seed are produced on underground branches by spikelets that do not open. This similarity to the common peanut or "goober," *Arachis hypogaea* L., inspired the common name.

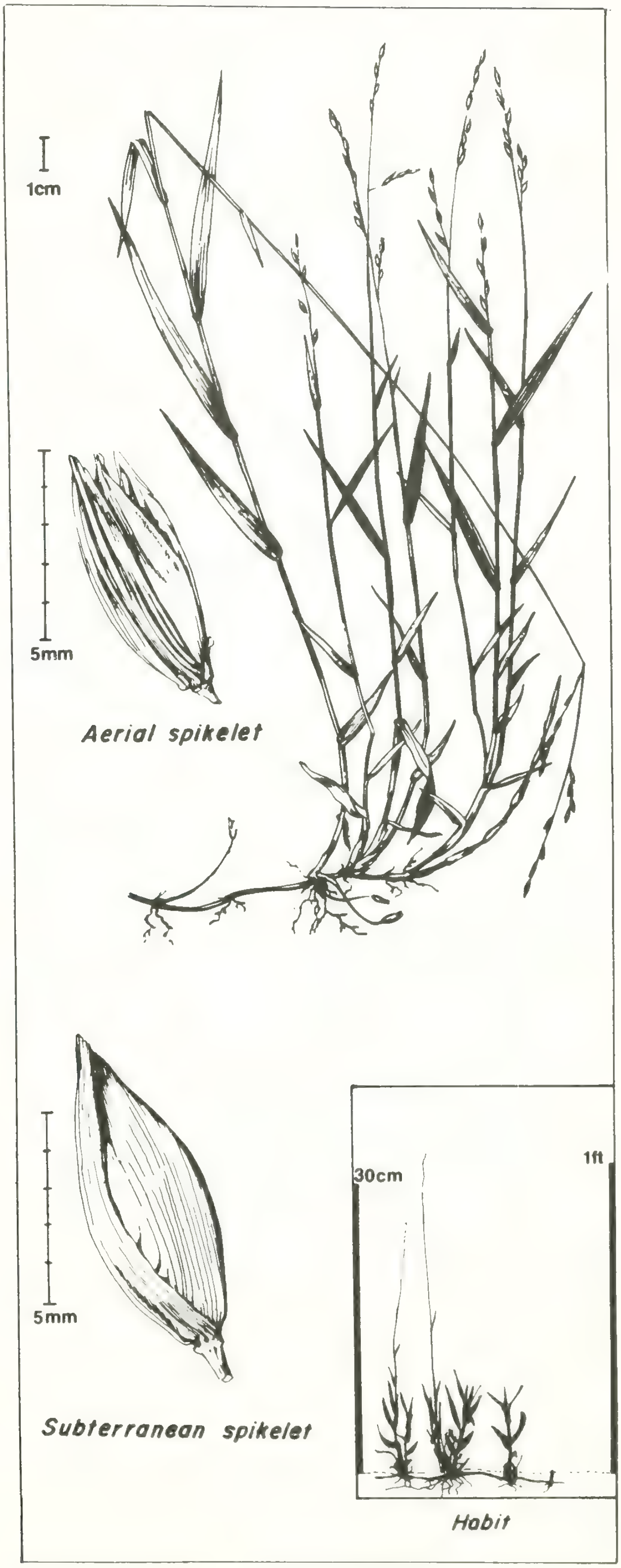
Stalks arise from a slender rhizome, producing a spikelike panicle about 5 inches long, with few flowers. Plants are 1 to 3 feet tall, with decumbent stems. Leaves are about 2½ inches long and ¼ inch wide. They are hairless except for occasional marginal hairs. Blades are conspicuously white-margined.

Goobergrass grows in pure stands on wet sandy flats, shallow ponds, or sloughs; it will not grow where water depth permanently exceeds 6 or 8 inches. Cattle graze it yearlong and deer utilize it in winter.

A hairy annual species, *Amphicarpum purshii* Kunth, grows from Georgia to New Jersey.

Range: South Alabama, Florida, coastal Georgia, and southeastern South Carolina.

Perennial. **Culms** usually decumbent at base, 30 – 100 cm tall, rhizomatous; **leaves** firm, blades white-margined when dry, 10 cm or less in length, 5 – 10 mm wide; **panicle** narrow, long-exserted, few-flowered; **spikelets** narrowly lanceolate, 6 – 7 mm long, subterranean spikelets 6 – 9 mm long.



Green Silkyscale—*Anthaenantia villosa* (Michx.) Beauv.

Green silkyscale is most common on longleaf-slash pine range. It grows on sandy sites, frequently in association with Elliott bluestem and paintbrush bluestem.

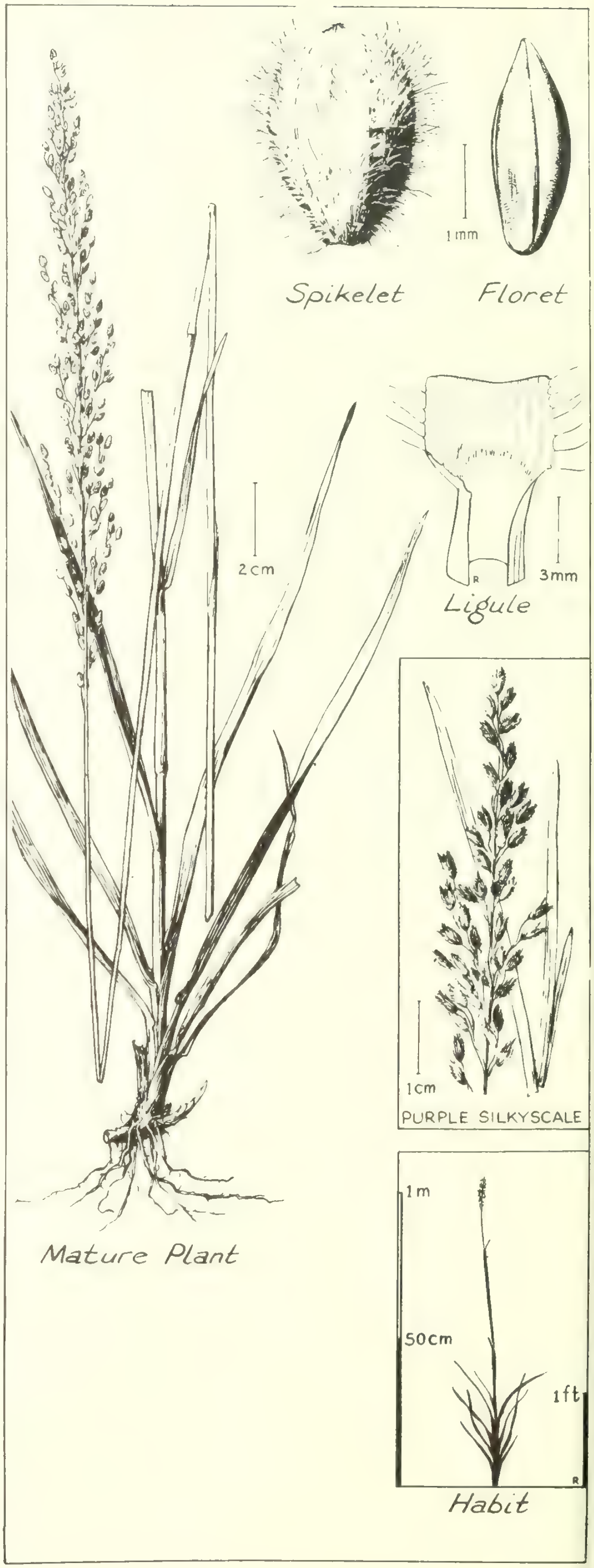
Mature plants are about 3 feet tall and spread by short rhizomes. In heavy bluestem stands, they usually form small, irregular, densely tufted clumps. Where soil is unusually fertile, clumps of plants may occasionally attain basal diameters of 10 to 12 inches. The smooth, pea-green, twisted foliage is conspicuous among other grasses. Basal leaves frequently reach 1 foot in length, but upper leaves are very short. Blades are about ¼ inch wide, most tapering abruptly to a point at the tip. Leaf margins are fringed with short hairs, and blades have no prominent midrib. The inflorescence is a narrow panicle up to 7 inches long. Spikelets are green, conspicuously fuzzy, about ⅛ inch long, and ovoid in shape.

Purple silkyscale, *Anthaenantia rufa* (Ell.) Schult., also grows throughout the southern Coastal Plain, usually on wetter sites than green silkyscale. It can be distinguished from green silkyscale either by its purplish spikelets or the lack of hairs on leaf margins.

Green silkyscale foliage is palatable and nutritious, but its grazing value is limited by its lack of abundance.

Range: Coastal Plain, Texas to Florida and North Carolina.

Perennial. **Culms** 60 – 120 cm tall, slender, in small tufts or singly from short rhizomes; **sheaths** glabrous, nonkeeled, much shorter than the internodes, crowded and overlapping at the base of the plant; **ligule** a short, ciliate membrane; **blades** 5 – 10 mm wide, glabrous with ciliate margins, flat, twisted along the length one to several times, tapered at the apex, the basal blades 10 – 30 cm long, the upper ones much reduced; **panicle** 10 – 17 cm long, pale green, long-exserted above the last reduced blade; **spikelets** 3 – 4 mm long, stalked, solitary, obovoid, with rows of long hairs between the nerves on the second glume and sterile lemma; **first glume** wanting; **grain** 2.5 mm long, brown, shining.



Arrowfeather Threeawn—*Aristida purpurascens* Poir.

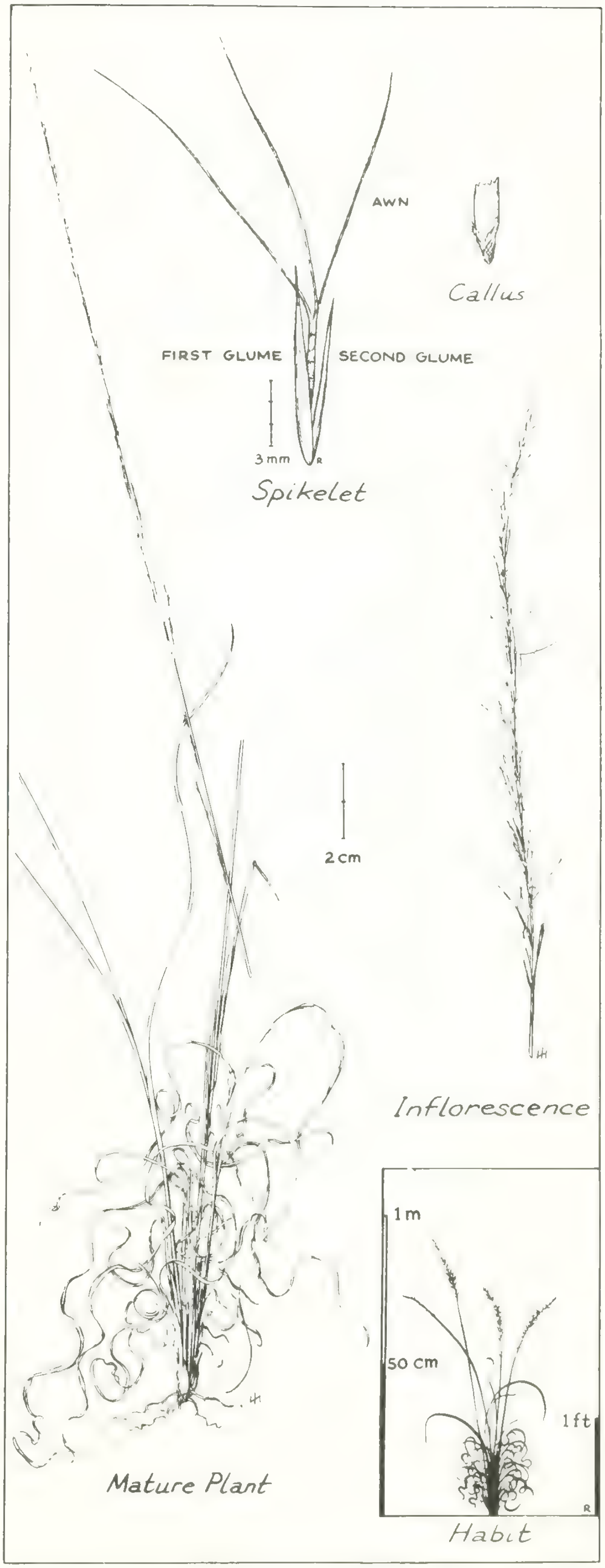
Arrowfeather threeawn is common on longleaf-slash pine sites across the South. It grows on dry sandy sites and increases in abundance on overgrazed range.

It is a perennial with mostly basal leaves and forms dense clumps that are usually less than 3 inches in diameter. Flower stalks, which mature in the fall, average 2 feet tall. The inflorescence is a narrow, nodding panicle 6 to 12 inches long. Spikelets are round in cross section and one-flowered. They terminate in three spreading awns, each about ¾ inch long. Exclusive of awns, spikelets are about ⅜ inch long. Although panicles may become purplish toward maturity, this color is less characteristic than *purpurascens* implies. The thin papery glumes, up to ½ inch long, persist after spikelets shatter. Foliage curls conspicuously in the fall, with many of the leaf blades forming one or more ringlets.

Arrowfeather threeawn is low in forage value. Cattle may graze it in spring, especially on freshly burned range. Palatability declines after early summer, as the foliage becomes tough and somewhat wiry.

Range: Texas to Florida, extending north to Wisconsin and Massachusetts.

Perennial. **Culms** 40 – 70 cm tall, slender, in tufts of several stems from a weak, knotty base; **sheaths** smooth and glabrous; **ligule** a short-ciliate membrane less than 0.5 mm long; **blades** 1 – 2 mm wide, flat, to 20 cm long, sometimes with a tuft of long hairs above the ligule, long-acuminate, in age forming curls or ringlets; **panicle** 15 – 30 cm long, one-third to one-half the total length of the culm, the branches short, appressed; **spikelets** with three straight spreading awns 12 – 25 mm long, the center one sometimes slightly exceeding the others in length; **glumes** 6 – 12 mm long, the first longer than the second, scabrous; **lemma** 6 – 8 mm long, hispid, sometimes marked with six to eight diagonal dark-purple bands, the callus about 0.5 mm long, pubescent; **anthers** purple.



Bottlebrush Threeawn—*Aristida spiciformis* Ell.

This showy perennial grass is common on disturbed or overgrazed Coastal Plains flatwoods sites from Mississippi to South Carolina, but has little worth as forage. It is found on seepage slopes and occasionally on well-drained uplands. The 6- to 8-inch bristly seed head on the bare stalk resembles a bottle brush.

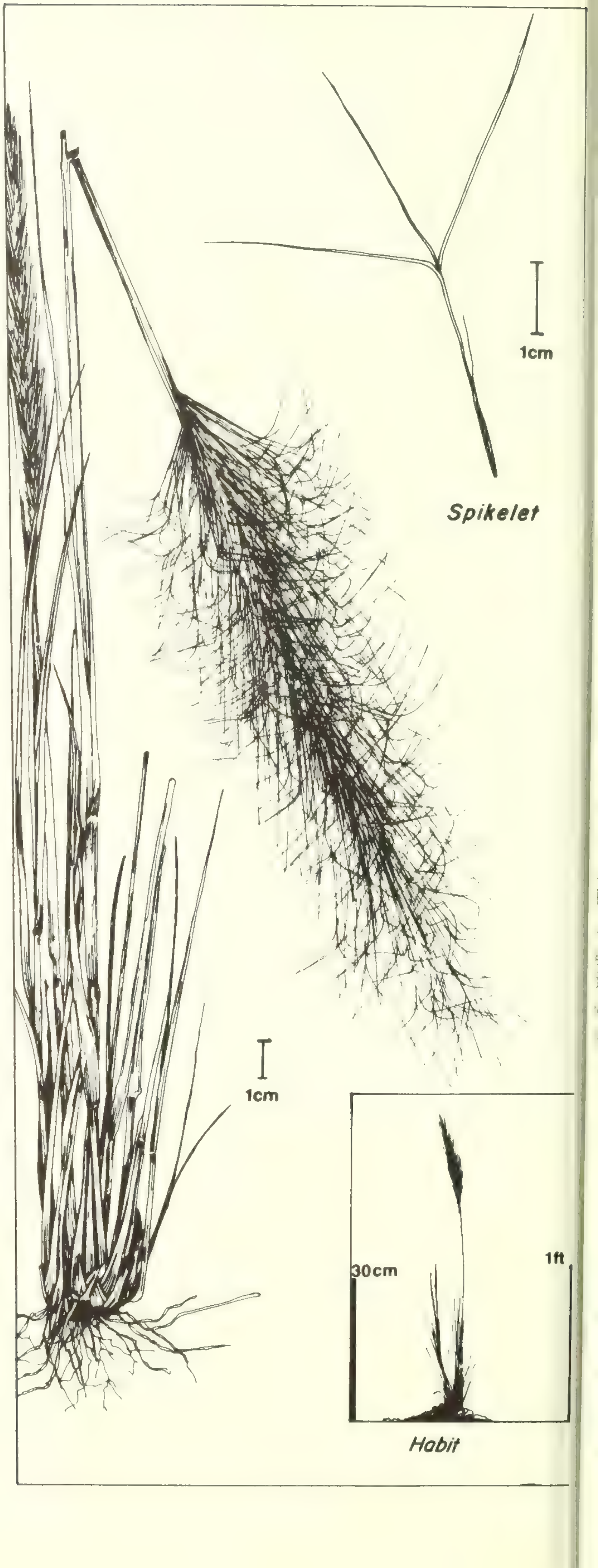
Like most threeawns, bottlebrush threeawn grows best where competition is light. It is a short-lived perennial that depends on its abundant seed production for reproduction.

Plants produce very little forage even where stems are dense. Cattle avoid plants after the bristly seed heads form in late August and September. The large seed head distinguishes bottlebrush from pineland and arrowfeather threeawns.

Several annual threeawns are common and often abundant on roadsides, overgrazed range, and other disturbed sites. Churchmouse threeawn, *Aristida dichotoma* Michx., oldfield threeawn, *A. oligantha* Michx., and slimspike threeawn, *A. longespica* Poir., are three annuals with southwide distribution.

Range: Coastal Plain, Mississippi to central Florida and South Carolina.

Perennial. **Culms** erect, 50 – 100 cm tall, glabrous; **blades** 1 – 3 mm wide, elongate, stiffly erect, involute, glabrous; **sheaths** glabrous; **panicle** dense and spike-like, 10 – 25 cm long; **glumes** unequal, the first 4 – 5 mm long, about half as long as second, both awned; **lemma** 1 – 3 cm long including column, awns subequal, 2 – 3 cm long.



Pineland Threeawn—*Aristida stricta* Michx.

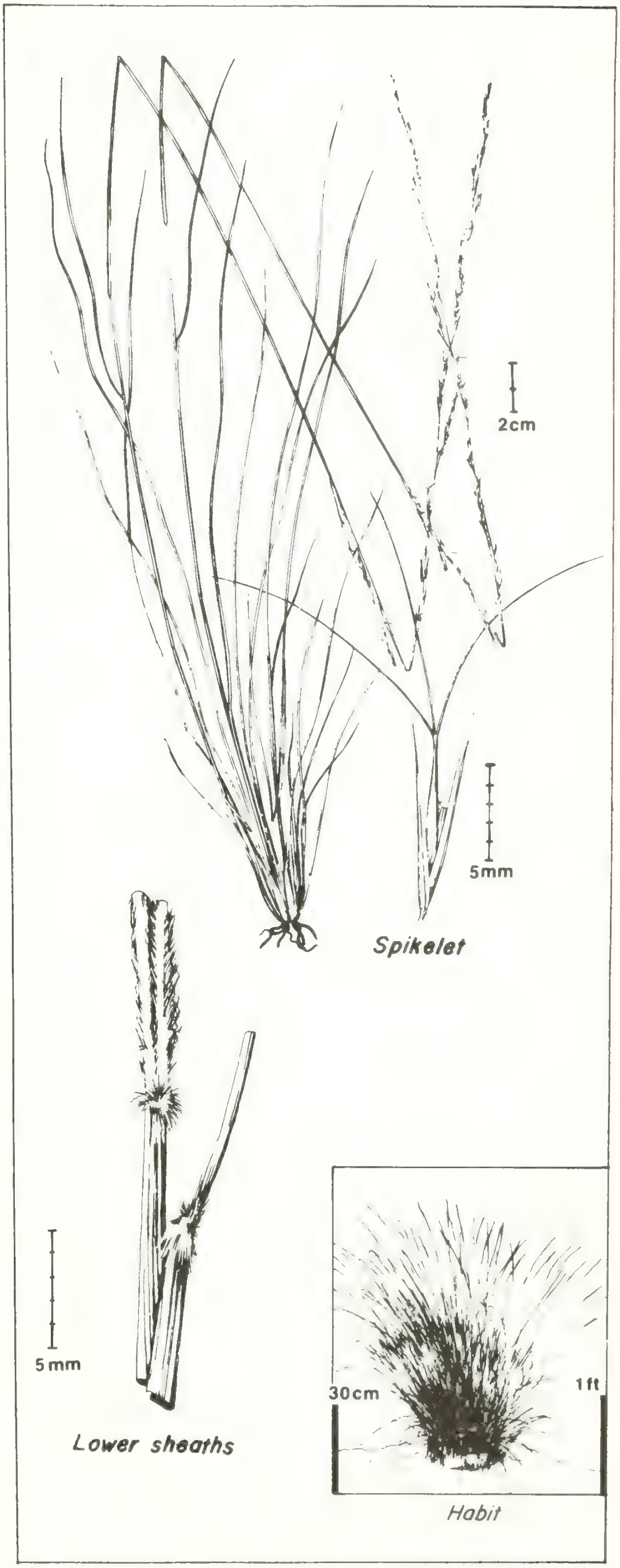
This is the "wiregrass" of the southeastern Coastal Plain. It is a principal forage grass of pine flatwoods range in Florida and Georgia. Although it withstands heavy grazing and frequent burning, it is palatable and nutritious for livestock only for a short time after a fire. Abundant seedstalks are produced by midsummer, following an early spring burn. Two or three years with no burning reduces seedstalk production drastically, and a dense wiregrass rough builds up. Very little grazing is possible on wiregrass range without prescribed fire. Plants with seedstalks are about 3 feet tall. Stalks are erect and slender with a spikelike terminal panicle about 12 inches long. Leaf blades are tightly rolled and tough except in very new growth. Recently burned plants have stiffly ascending leaves and seedstalks, appearing quite different from the stalkless, spreading clumps in the unburned rough.

Cutover muhly is similar in growth habit to pineland threeawn, but its leaf blades are not as tightly rolled. A distinguishing characteristic of pineland threeawn is a conspicuous band of white hair covering the collar, lower blade, and upper sheath of the lower leaves.

Dense colonies of pineland threeawn are found in the wet sandy flatwoods of the pine-wiregrass type. The grass is also the dominant herbaceous plant on dry sandhills. When eliminated from a site, as by chopping, it does not return, indicating that few viable seeds are produced.

Range: Mississippi to Florida and North Carolina.

Perennial. **Culms** 50 – 100 cm tall, glabrous; **leaves** densely tufted, mostly basal, **blades** involute, elongate, to 50 cm long; **collar** densely pilose; **panicle** slender, to 30 cm long; **glumes** 7 – 10 mm long, **lemma** 6 – 8 mm long, scarcely beaked; **awns** divergent, the central 1.0 – 1.5 cm long, the lateral slightly shorter.



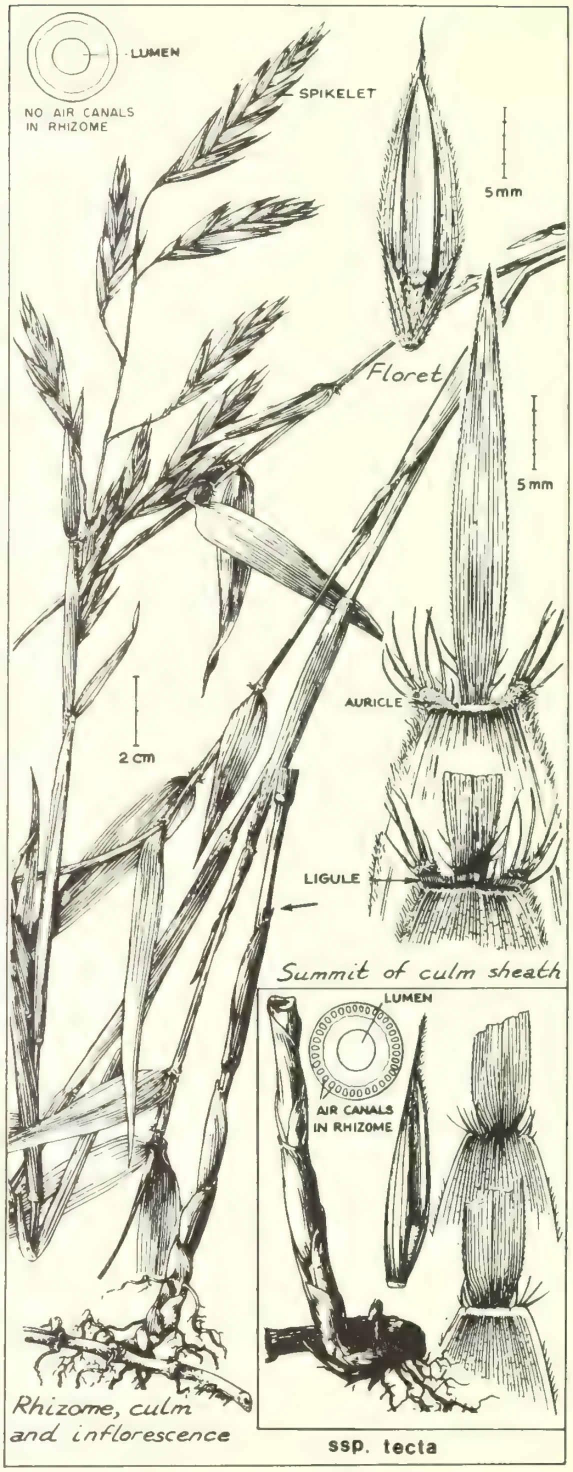
Cane—*Arundinaria gigantea* (Walt). ex Muhl.

Until recently, switch cane and giant cane were considered two separate species of *Arundinaria;* switch cane was *A. tecta* and giant cane was *A. gigantea.* McClure (1978) changed the rank of switch cane to subspecies *tecta* of *A. gigantea,* made giant cane *A. gigantea* spp. *gigantea,* and separated a third subspecies, *A. gigantea* spp. *macrosperma.* No attempt will be made here to distinguish between subspecies as differences are based primarily on the presence or absence of air canals in the rhizome (see illustration) and are not always conclusive.

Cane is the largest native grass in the United States. On moist, fertile bottomlands, it may reach 25 feet in height with stems up to ¾ inch in diameter. Scattered small plants may be found on uplands adjacent to bottomlands. Unlike most other grasses, it is an evergreen shrub, the stems surviving for several years. Cane does not flower often enough to be identified by usual taxonomic procedures but is easily distinguishable from other grasses by its stout, hollow, jointed stems similar to cane fishing poles. Wide leaf blades are narrowed to short petioles. On upland sites, plants flower following grazing or burning.

Cane is excellent forage. Cattle graze leaves and twigs during winter, when other green herbage is scarce. On an experimental range in North Carolina, cane was grazed from May until January and furnished 70 to 93 percent of the cattle diet. Crude protein, calcium, and phosphorus content of cane averaged higher than in other grasses studied and well above the requirements of growing cattle. Under careful management, grazing capacity was high; ½ to 1 acre per cow-month. Despite its high nutritive value, cane is not abundant enough on upland sites to be considered an important range forage plant. Although extensive canebrakes were once common along many streams, most have been seriously depleted by overuse. Burning to reduce height, followed by concentrated grazing, eliminated many stands. Large brakes can be very productive if judiciously managed. Where cane furnishes a minor part of the forage, it is usually overgrazed.

Range: Southern and southeastern states from Texas and Oklahoma, extending eastward to West Virginia, Delaware, and Florida.



Perennial. **Culms** 1 – 8 m tall, erect, smooth, and woody, to 2 cm in diameter, arising abruptly from a stout rhizome; lower culm sheaths about half as long as the internode, withering and soon falling; upper culm sheaths with 10 to 12 bristles 6 – 9 mm long at the summit, occasionally growing out of a definite pair of auricles, a dense band of stiff hairs across the collar; **ligule** firm, scarcely 1 mm long; **leaf blades** petiolate, rounded at the base, acuminate at the tip, glabrous to pubescent, 15 – 27 cm long, 2.5 – 4.0 cm wide on the main culm and primary branches, shorter and narrower on the ultimate branchlets, often in dense flabellate clusters; **inflorescences** paniculate or racemose, crowded toward the ends of leafy or leafless twigs with few to several spikelets on slender, angled pedicels 2 – 30 cm long, hirsute to nearly glabrous; **spikelets** 4 – 7 cm long, about 8 mm wide, mostly with 8 to 12 flowers, rather loose; **glumes** distant, acuminate, pubescent, the lower sometimes wanting; **florets** 1.5 – 2.0 cm long, the keeled, broadly lanceolate lemma tapering to an awn about 4 mm long.

Common Carpetgrass—*Axonopus affinis* Chase

Carpetgrass differs markedly in growth habit from most southern range grasses. Under favorable conditions it spreads rapidly by stolons, developing a dense sod. The best carpetgrass site is a moist, medium- to fine-textured soil where grazing is intense. On dry sandy soils it occurs sparingly, growing in shallow depressions or as small, widely scattered colonies along animal trails and on intensely grazed areas.

Where use is light, carpetgrass cannot compete successfully with taller grasses. On a Louisiana range that had been grazed heavily for 12 years, it comprised 15 percent of the vegetation. Three years after grazing was discontinued it declined to 3 percent.

Slender flower stalks up to 2 feet tall are produced throughout the growing season. The inflorescence consists of two to four slender racemes 1 to 3 inches long. Leaf blades are mostly 4 to 6 inches long and about ¼ inch wide, with bluntly rounded tips.

The foliage of carpetgrass resembles centipedegrass, *Eremochloa ophiuroides* (Munro) Hack., and St. Augustinegrass, *Stenotaphrum secundatum* (Walt.) Kuntze. Its inflorescence consists of several racemes, however, while those of the other grasses are solitary spikes.

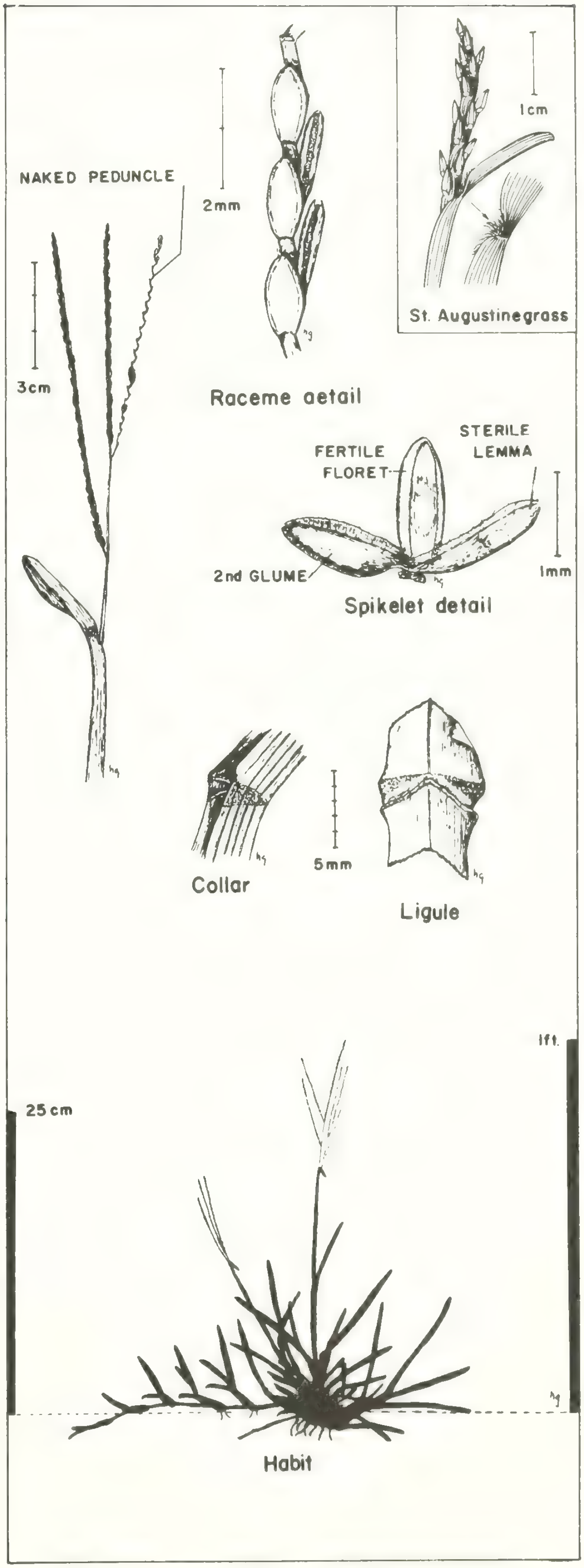
Big carpetgrass, *Axonopus furcatus* (Fluegge) Hitchc., and tropical carpetgrass, *A. compressus* (Swartz) Beauv., also grow on southern pine forest ranges. Their characteristics and forage values are similar to those of common carpetgrass. Both are usually found on wetter sites than those occupied by common carpetgrass.

Common carpetgrass is nutritious and highly palatable throughout the growing season. Although cattle usually prefer it over most of the associated grasses, it is too sparse on well-managed ranges to contribute much forage. Grazing intensely enough to maintain carpetgrass stands adversely affects soil conditions and pine regeneration; it also leaves little forage for winter use.

Carpetgrass is valuable mainly as cover on range areas grazed too heavily to support other perennial grasses. It is also useful for seeding grazed firebreaks, for it readily withstands the utilization pressure necessary to minimize fuel.

Range: Coastal Plain, North Carolina to Texas, extending north to Oklahoma and Arkansas.

Perennial. **Culms** slender, glabrous, 25 – 60 cm tall in erect tufts or from stolons; **sheaths** broad, compressed-keeled, glabrous; **ligule** membranous, less than 0.5 mm long, margin fringed; **blades** 2 – 6 mm wide, flat or folded, usually short in relation to the long sheaths, conspicuously rounded at the tip; **racemes** two to four, subdigitate, 2 – 10 cm long; **spikelets** about 2 mm long, oblong-elliptic, blunt at the tip, sparsely silky-pilose.



Longleaf Uniola—*Chasmanthium sessiliflorum* (Poir.) Yates—*(Uniola sessiliflora* Poir.)

With the exception of seaoats, *Uniola paniculata* L., all uniolas, known also as spikegrasses, are now in the genus *Chasmanthium.* Longleaf uniola is perhaps the most characteristic grass of the loblolly-shortleaf pine-hardwood type; in densely shaded stands, it may be the only grass present. It grows in loose tufts from short, knotty rhizomes. Stalks are erect to spreading or slightly nodding, from 2 to 4 feet tall. Although classified as a warm season perennial, it produces new growth sporadically during the winter and early spring. By late spring or early summer, vegetative growth ceases and seedstalks form. Seed do not mature until fall.

Leaf blades are 3 to 16 inches long and up to ½ inch wide, tapering toward both the tip and base. Blades are usually thinly coated with short white hairs on the lower surface. Upper surfaces are hairless except near the base. Sheaths are conspicuously hairy, especially at the summit.

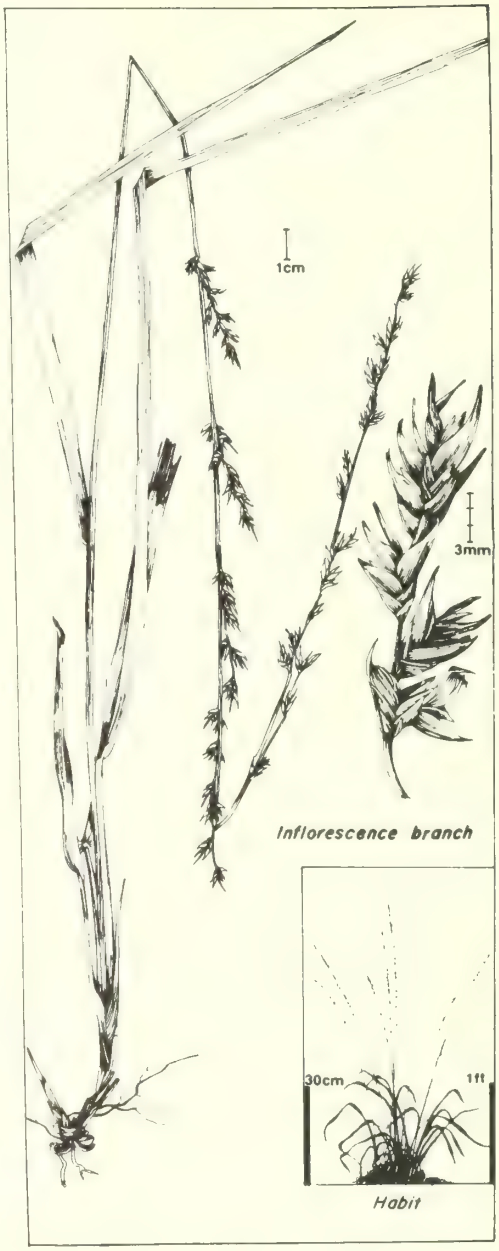
The inflorescence is a spike-like panicle 8 to 20 inches long with stiffly ascending or appressed branches up to 3 inches long. The flat, three- to five-flowered spikelets are clustered along the panicle branches. Mature seed are black, about $^1/_{10}$ inch long.

Despite its tolerance of fairly heavy shade, longleaf uniola produces more forage in stands opened up by thinning or removal of weed trees and brush. However, it cannot tolerate full sunlight. The uniolas rank below the bluestems in quantity and quality of forage produced, but the value is enhanced by winter burning, which destroys old growth and promotes early regrowth. New growth following a winter fire is palatable and comparable to the better bluestems in protein content. By the time seedstalks appear in early summer, however, palatability is much below that of the bluestems, although protein content remains relatively high. Some foliage retains a green color throughout the winter.

Spike uniola, *C. laxum* (L.) Yates, is similar in appearance and growth habit to longleaf uniola. The two grow together throughout the South, but on pineywoods range, longleaf uniola is usually most abundant. Spike uniola, which has hairless foliage, narrower leaves, and a more nodding seedstalk than longleaf, is generally more common on sites somewhat wetter than those occupied by longleaf uniola. The conspicuously hairy sheaths of longleaf uniola are the most reliable distinguishing characteristics; spike uniola is hairless. The two grasses are similar in forage value as well as in appearance; thus, there is little need to distinguish between them.

Broadleaf uniola, *C. latifolium* (Michx.) Yates, has leaves up to 1 inch wide and is found on shaded, sandy streambanks throughout the South. Its flat, several-flowered spikelets resemble those of seaoats more than those of other species of *Chasmanthium.*

Range: East Texas and Oklahoma to Florida and Virginia.



Perennial. **Culms** 50 – 150 cm tall, erect in loose tufts from short, knotted rootstocks; **sheaths** pilose, at least toward summit, densely pilose at collar; **blades** 8 – 38 cm long, 5 – 10 mm wide, firm, sparsely pilose on upper surface near base, puberulent on lower surface or merely short ciliate on margins; **ligule** short, membranous, finely ciliate; **panicle** long-exserted, 20 – 50 cm long, branches narrow, distant, ascending or appressed; **spikelets** in fascicles 1 – 3 cm apart, flat, 3- to 5-flowered, broadly v-shaped at maturity, 6 – 8 mm long; **glumes** 1.5 – 2 mm long, much shorter than lemmas; **first lemma** sterile; fertile lemma 3 – 5 mm long, acuminate, beaked, striate-nerved; palea shorter than lemma, acute; **grain** about 3 mm long, black.

Carolina Jointtail—*Coelorachis cylindrica* (Michx.) Nash—*(Manisuris cylindrica* (Michx.) Kuntze)

Recent revision of the genus *Manisuris* and related genera moved all southern species of *Manisuris* to the genus *Coelorachis,* an earlier name for the jointtails. Itchgrass, formerly *Rottboellia exaltata* L. f., is now *Manisuris exaltata* (L. f.) Kuntze. An agricultural weed throughout the South, itchgrass is now the only species in the genus *Manisuris.*

Carolina jointtail grows on sandy soils throughout the South, usually on disturbed sites such as firelines. In spring and early summer, plants are easily identified by the jointed, cylindrical, spikelike raceme at the tip of each flower stalk. Racemes are generally 3 to 6 inches long and about ⅛ inch in diameter. They shatter readily at maturity; plants may afterwards be recognized by the swollen joint at the stalk tip.

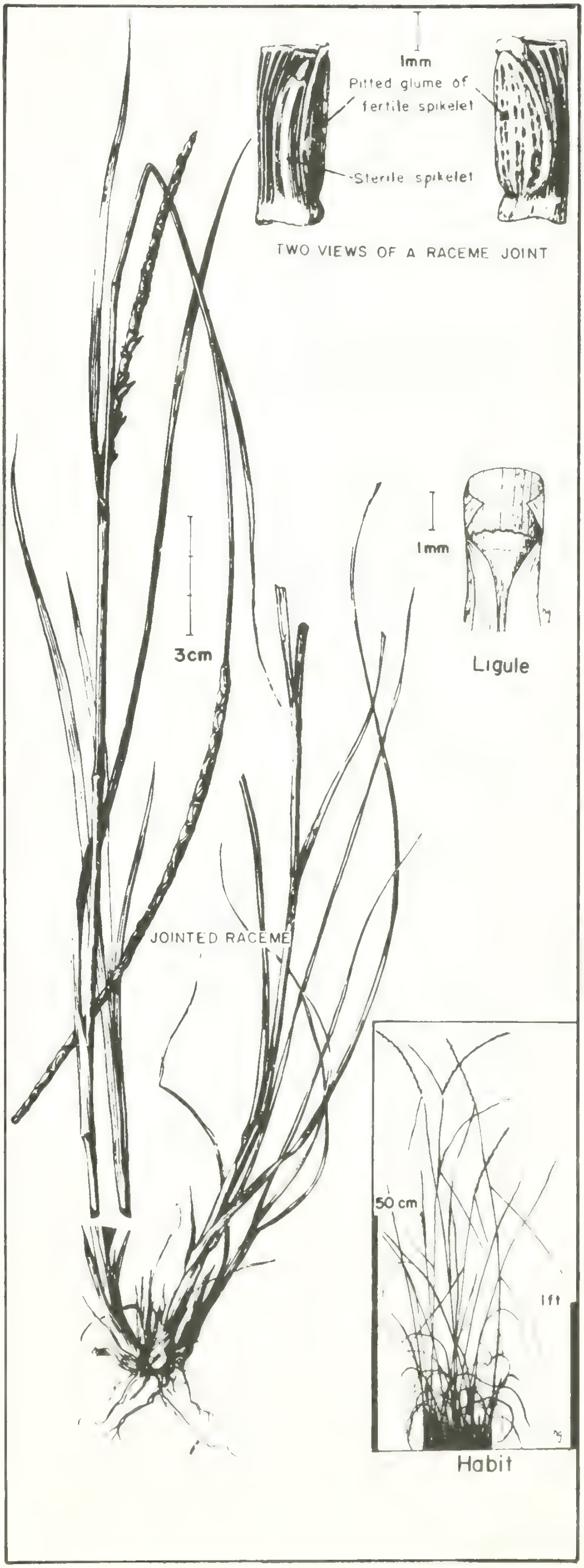
Carolina jointtail usually grows in small colonies. Since the seedbearing joints of the racemes are heavy, most seeds remain near the parent. New plants begin as small tufts, spreading by short rhizomes. Height at maturity is about 3 feet.

Lattice jointtail, *C. tessellata* (Steud.) Nash, and wrinkled jointtail, *C. rugosa* (Nutt.) Nash, also grow in the South, but not on dry sites. Both have flattened leaf sheaths; those of Carolina jointtail are round.

Carolina jointtail is palatable and nutritious until plants mature in late spring or early summer. It is apparently intolerant of heavy grazing.

Range: Texas to Florida, extending north to North Carolina and Missouri.

Perennial. **Culms** 30 – 100 cm tall, broad at the base, in tufts from short, stout rhizomes, erect, slender, generally unbranched; **sheaths** 2 – 3 mm wide, shorter than the internodes, cylindrical, sometimes reddish or purplish; **ligule** a short membrane, collar and nodes purple; **blades** 1 – 3 mm wide, to 30 cm long, slightly curved, flat or involute; **racemes** 10 – 20 cm long, cylindrical, purple, solitary on main culm and branches; **spikelets** awnless, in pairs at the nodes of a thickened rachis; **sessile spikelet** 4 – 5 mm long, perfect, first glume pitted along the nerves; **pedicellate spikelet** reduced to two scales.



Toothachegrass—*Ctenium aromaticum* (Walt.) Wood

Toothachegrass commonly inhabits flatwoods sites in cutover areas. It is commonly found on sandy bogs, where pitcherplants *(Sarracenia* spp.) are the dominant plants. These may be narrow hillside bogs between a creek and a sandy pine hill.

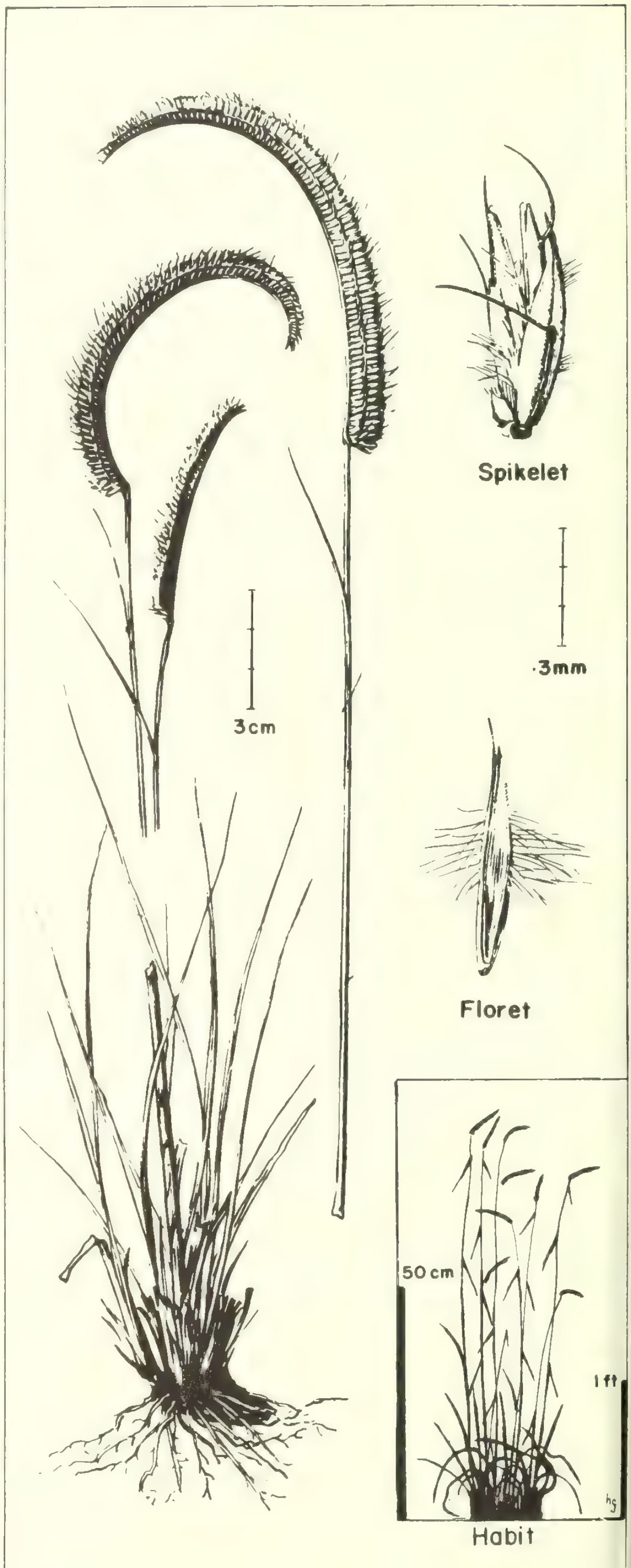
The plants are conspicuous, growing in clumps with scant foliage and many erect flower stalks 3 to 5 feet tall. Each stalk ends in a solitary, thick, usually curving, comblike spike 2 to 6 inches long. Spikelets, crowded on one side of the axis, bear a straight awn about ¼ inch long. Except for *Ctenium floridanum* (Hitchc.) Hitchc., which is restricted to Florida, no southern grass has an inflorescence resembling that of toothachegrass.

The foliage of toothachegrass is distinguishable from other grasses by the fibrous mat that remains after old leaf sheaths disintegrate. Although it resembles cutover muhly in this character, its fibers are straight to gently curving, not curly as in cutover muhly. Its leaf blades are up to ¼ inch wide; those of cutover muhly are less than ⅛ inch wide. Freshly dug roots emit a distinctive spicy odor; the substance responsible is reputedly effective in relieving toothache. Chewing the roots produces a slight numbness in the tongue and gums.

On unburned range, the persistent old leaves and flower stalks make toothachegrass relatively unpalatable. After a fire, cattle readily graze the herbage.

Range: Coastal Plain, Louisiana to Florida and Virginia.

Perennial. **Culms** stout, unbranched, 10 – 150 cm tall, from aromatic roots; **sheaths** shorter than the internodes, ribbed, glabrous, persistent, the old ones forming a conspicuous fibrous mass at the base; **ligule** about 1 mm long, membranous, truncate; **blades** 2 – 6 mm wide, flat or involute, elongate with attenuate tips; **inflorescence** a single straight or curved thick spike 5 – 15 cm long; **spikelets** 5 – 7 mm long, arranged on one side of the pubescent rachis.



Poverty Danthonia—*Danthonia spicata* (L.) Beauv. ex R. & S.

Poverty danthonia, known also as poverty oatgrass, povertygrass, or junegrass, is a weedy cool-season perennial bunchgrass found along roadsides and on rocky, sandy, generally dry or sterile sites throughout most of the United States. In the South, it is found most frequently in the loblolly-shortleaf pine-hardwood and upland hardwood-bluestem types.

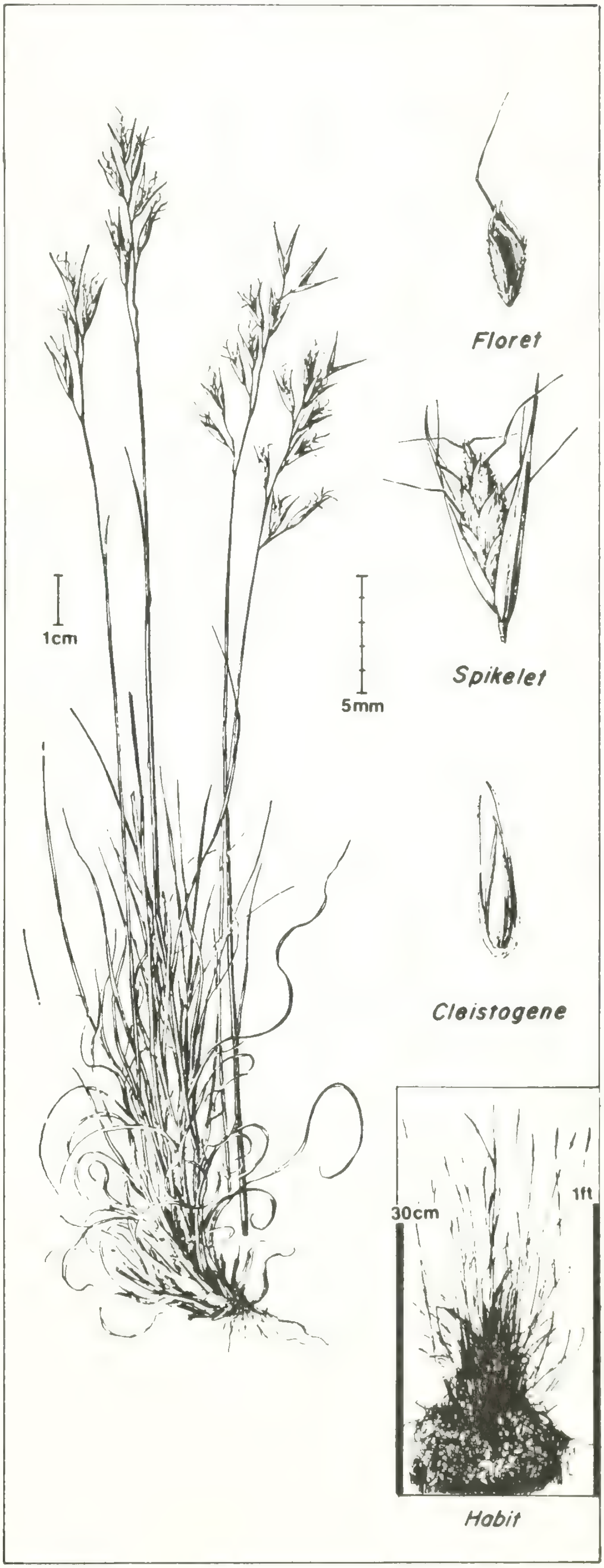
Plants average about 1½ feet in height, seldom exceeding 2 feet. Most of the foliage is in a crowded basal clump of leaves, with narrow blades 4 to 6 inches long and often curved or twisted. A constricted panicle of 2 to 13 spikelets terminates each culm. A reduced spikelet with a single unopened, self-fertilized floret (cleistogene) is produced inside one or more leaf sheaths.

Two other closely related species, flatstem danthonia, *Danthonia compressa* Austin, and downy danthonia, *D. sericea* Nutt., occur on southern forest ranges. Flatstem danthonia, which overlaps the range of poverty danthonia at the mountainous eastern end of the loblolly-shortleaf pine-hardwood type, has crooked culms and a much looser inflorescence than poverty danthonia. Downy danthonia, a larger and hairier species, occurs throughout the South, and is common but not abundant in longleaf pine forests of southern Alabama and northwest Florida.

Cattle, deer, and wild turkeys eat the young basal foliage of poverty danthonia, but the plant is considered an indicator of abused range or poor soils. Western varieties reportedly have no forage value. Seeds of both poverty and downy danthonias have limited value as food for wildlife.

Range: From Maine and Florida to Washington, Oregon, and New Mexico. Rare in the Coastal Plain.

Perennial. **Culms** erect, straight, 20 – 60 cm tall, densely cespitose; **leaves** mainly basal; **sheaths** glabrous or occasionally pilose, a tuft of long hairs at the throat; **blades** up to 20 cm long, 2 mm wide, involute; **inflorescence** a contracted panicle 2 – 5 cm long with 2 to 13 spikelets; **spikelets** 5- to 8-flowered; **glumes** lanceolate-acuminate, 10 – 12 mm long; **lemma** 3.5 – 5.0 mm long, sparsely villous, awned from bifid apex, 4.5 – 9.0 mm; **palea** broad flat obtuse, ciliolate, reaching to base of awn; **cleistogamous spikelet** usually of one fertile, unawned floret slightly larger than normal florets.



Hairy Crabgrass—*Digitaria sanguinalis* (L.) Scop.

Hairy crabgrass is the most common of the southern crabgrasses. A native of Europe, it is thoroughly naturalized and is a weed of lawns and cultivated ground throughout the United States. On native range, it occurs on firelines, roadsides, and areas denuded by overgrazing or mechanical disturbance. It is a spreading, warm-season annual, rooting at the nodes of reclining stems. On rich soils, with little or no competition, it may form large clumps. Stems may be 3 feet, but the height of the clump is seldom more than 18 inches.

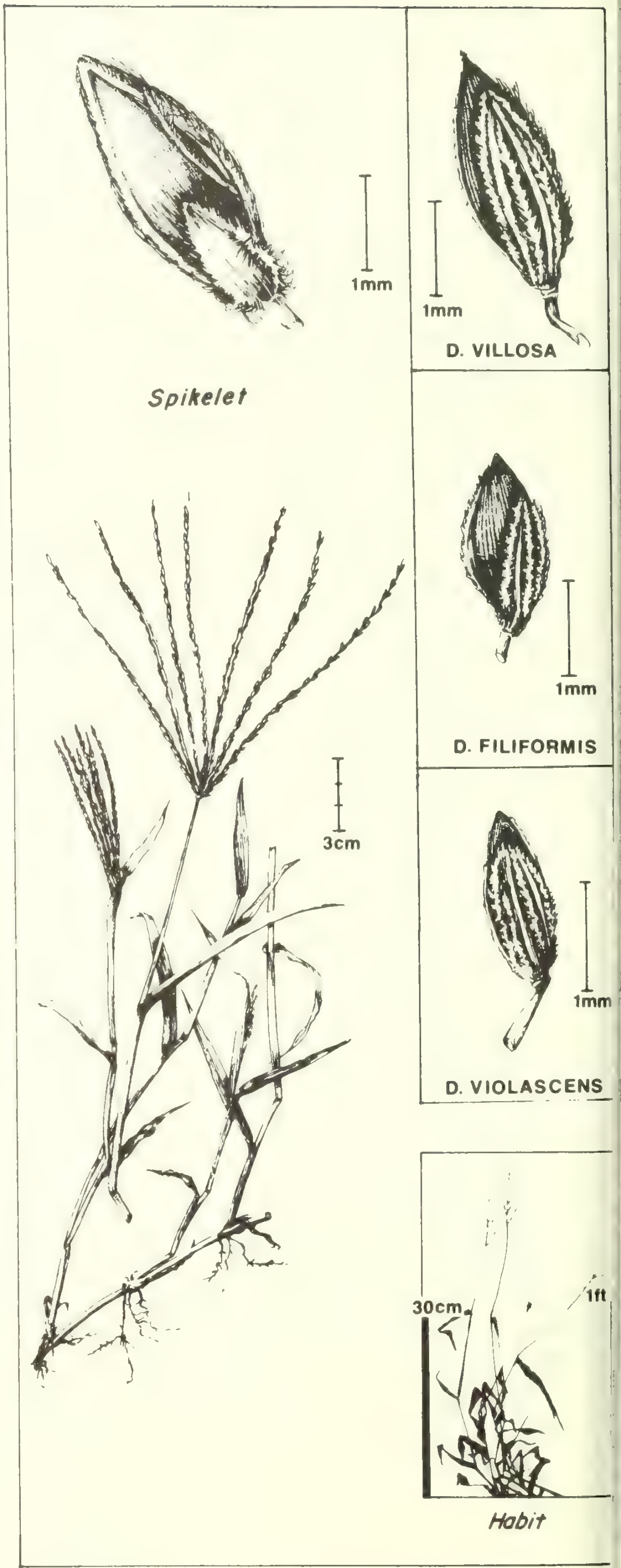
The closely related southern crabgrass, *Digitaria ciliaris* (Retz.) Koeler *(D. adscendens* (H.B.K.) Henr. or *D. sanguinalis* var. *ciliaris* (Retz.) Parlat.), is widespread and may be mistaken for hairy crabgrass. Southern crabgrass has glabrous or sparsely papillose-pilose foliage and glabrous nerves on the sterile lemma; hairy crabgrass foliage is densely pilose, and nerves of the sterile lemma have short vitreous spines.

Other common crabgrasses include violet crabgrass, *D. ischaemum* var. *violascens* (Link) Radf., *(D. violascens* Link), slender crabgrass, *D. filiformis* (L.) Koel., and shaggy crabgrass, *D. villosa* (Walt.) Pers. All three are found throughout the South and have dark-brown seeds. Seeds of hairy crabgrass are pale in color. There are approximately a dozen other crabgrasses in the United States with about half of them found only in southern Florida.

Spring growth is of good quality for cattle forage, but plants mature early, becoming dry and unpalatable. Since it seldom occurs on undisturbed ranges, however, little crabgrass forage is included in the cattle diet.

Range: Throughout the United States.

Annual. **Culms** branching and spreading, decumbent, rooting at lower nodes, finally erect or ascending, 30 – 120 cm long; **sheaths**, at least the lower, papillose-pilose; **ligule** erose, 2 – 3 mm long; **blades** to 16 cm long, 5 – 10 mm wide; **racemes** three to nine, 5 – 10 cm long, digitate; **spikelets** pale or grayish, about 3 mm long; **first glume** minute, **second glume** approximately one-half spikelet length.



Virginia Wildrye—*Elymus virginicus* L.

Virginia wildrye, or Terrellgrass, is a cool-season, weakly perennial bunchgrass occurring in several varieties throughout most of the United States. Although not a common plant of the pine forests, it grows in all the southern states. Stream borders, pond shores, moist swales, and rich woods are common habitats. New plants are produced by tillering as well as by seed.

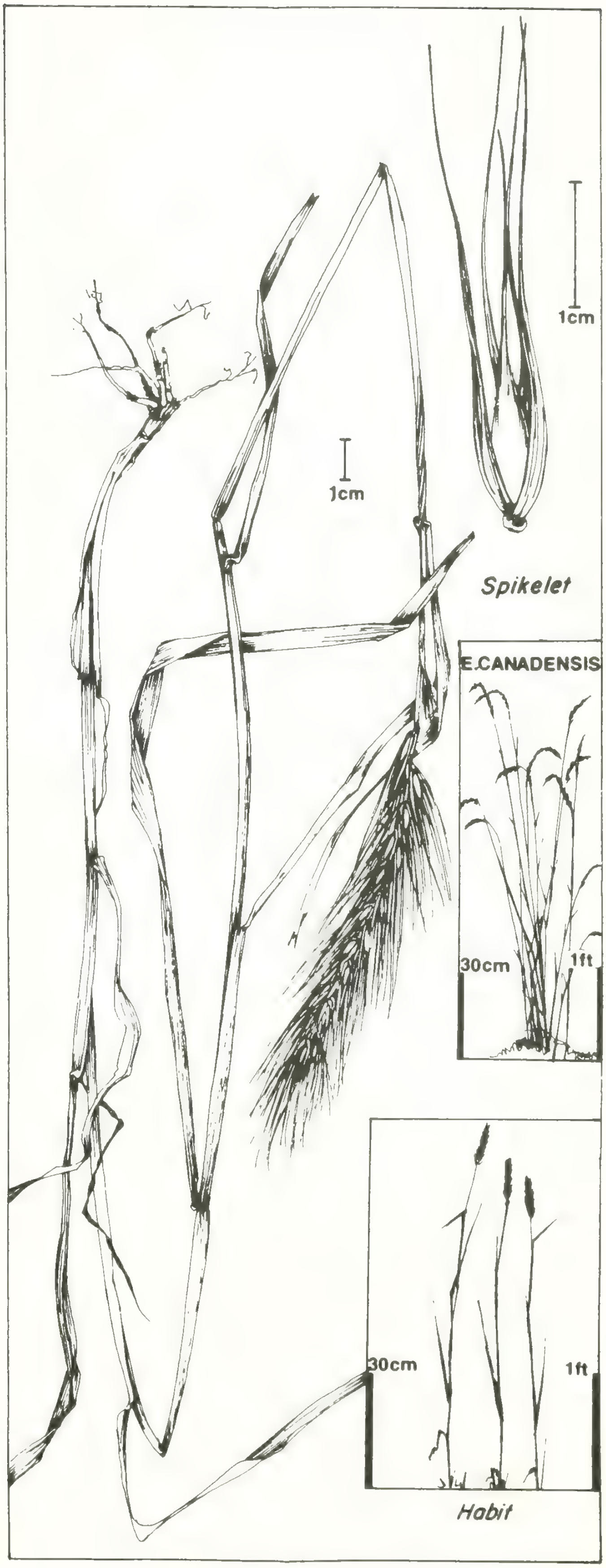
Stalks are 2 to 3 feet tall with erect seed heads. Leaf blades are up to 12 inches long, gradually tapering to a fine point from a basal width of about ¼ inch. Stems, leaves, and seed heads are usually hairless. A good identification character of Virginia wildrye is the hardened rounded, usually bowed-out base of the glumes; no other wildrye has this feature.

Canada wildrye, *Elymus canadensis* L., grows throughout much of the range of Virginia wildrye, but is not common in Coastal Plain pine forests. The two may occupy the same site and much of the variation recognized within each species is attributed to hybridization. Canada wildrye is more common on prairies and roadsides and can usually be distinguished by its lax, nodding seed heads and broader, lance-shaped leaves. Several other wildryes, especially Texas wildrye, *E. interruptus* Buckl., and hairy wildrye, *E. villosus* Muhl., occur at the western and northern fringes of the loblolly-shortleaf pine type. In these areas, an appropriate plant manual should be consulted for positive identification.

Early foliage of Virginia wildrye is palatable and nutritious, but plants mature by early summer. Both Virginia and Canada wildrye are classed as "decreasers," plants that decrease in percent composition on overgrazed range. Plants apparently cannot tolerate fire and the widespread use of prescribed burning, usually accompanied by heavy grazing, further limits its abundance.

Range: Most of United States.

Perennial. **Culms** 60 – 120 cm tall, tufted, erect; **sheaths** glabrous or with inconspicuously ciliate margins; **ligule** less than 1 mm long, brown, membranous; **blades** 5 – 15 cm long, 4 – 8 mm wide, flat, scabrous; **inflorescence** a single spike 5 – 15 cm long, erect, often partly included in sheath of upper leaf; **spikelets** two per node, 3- to 5-flowered; **glumes** 12 – 15 mm long, scabrous, strongly nerved, except nerveless at bowed-out base, indurate, tapering into a straight awn about as long as the body; **lemmas** glabrous and nerveless below, scabrous and nerved above, 6 – 8 mm long tapering into straight awn 1 cm long; **palea** equal in length to body of lemma; **grain** encased in lemma and palea, disarticulating above the glumes.



Purple Lovegrass—*Eragrostis spectabilis* (Pursh) Steud.

With its large colorful inflorescence fully expanded, purple lovegrass is among the showiest of southern grasses. Until the panicles emerge in late summer, however, the plants are relatively inconspicuous. This grass grows mainly on sandy ranges that have been grazed heavily or burned frequently.

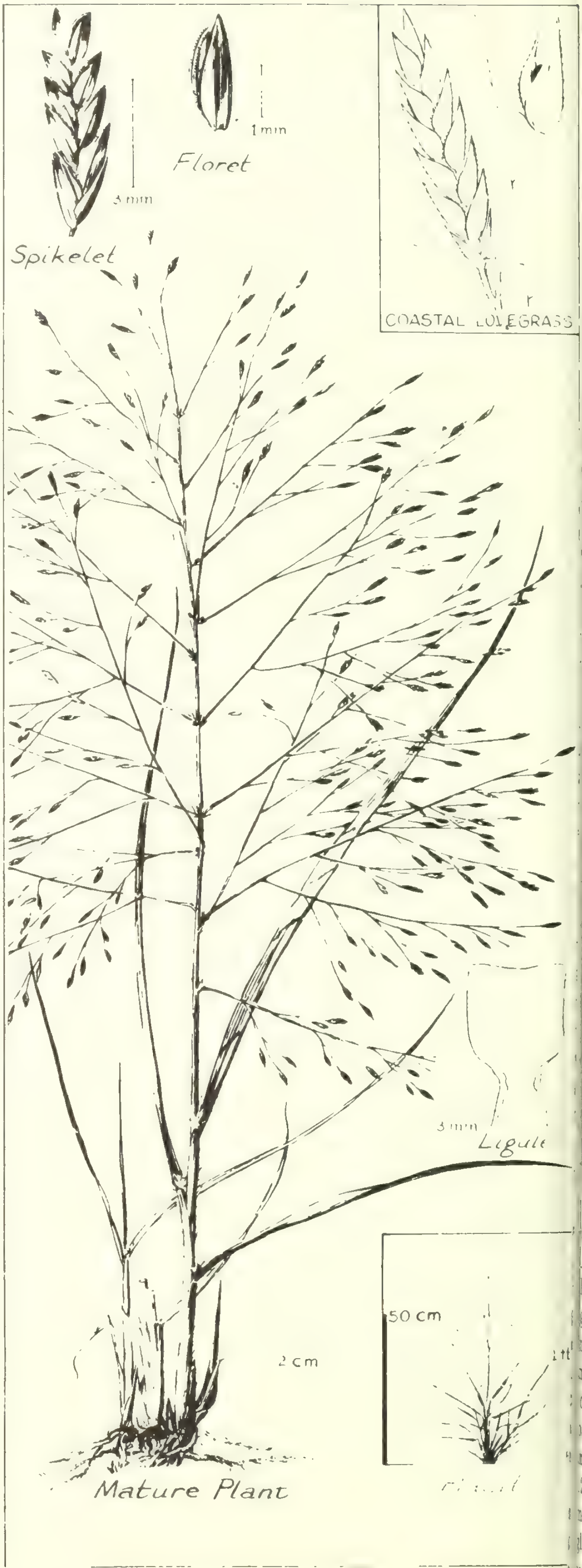
Mature plants are 1 to 2 feet tall, with the panicle usually two-thirds the height and about as broad as long. At maturity, panicles break away from the stalk to become "tumbleweeds." Leaf blades are 6 to 12 inches long and ⅛ to ⅜ inch wide, tapering to a fine point.

Coastal lovegrass, *Eragrostis refracta* (Muhl.) Scribn., and Elliott lovegrass, *E. elliottii* S. Wats., resemble purple lovegrass in size and growth habit. Their panicles are green to dark gray with delicate branches, whereas panicles on purple lovegrass are bright purple with comparatively rigid branches. Spikelets of coastal lovegrass are essentially sessile on panicle branches, while those of Elliott lovegrass are on long capillary pedicels.

In the spring, purple lovegrass foliage is palatable and nutritious. With emergence of the inflorescence in late summer, palatability declines rapidly. Plants are rarely abundant enough to supply significant amounts of herbage.

Range: Arizona to Minnesota, extending east to Maine and Florida.

Perennial. **Culms** 30 – 75 cm tall, in tufts from a knotty, rhizomatous base; **sheaths** longer than the internodes, overlapping, glabrous to pilose, conspicuously long-pilose at the summit; **ligule** a short, ciliate membrane 0.2 mm long backed by a ring of silky hairs 2 – 4 mm long; **blades** 3 – 8 mm wide, to 30 cm long, taper-pointed, stiff, flat, scabrous above, smooth beneath, ascending, glabrous to pilose; **panicle** 15 – 45 cm long, ovoid, about two-thirds the entire height of the plant, branches minutely scabrous, strongly pilose in the axils; **spikelets** 4 – 8 mm long, about 2 mm wide, on long pedicels, 5- to 12-flowered, purple; **florets** about 1.6 mm long, keels of the palea short-ciliate and bowed out; **grain** 0.6 – 0.8 mm long, brown.



Bent-Awn Plumegrass—*Erianthus contortus* Baldw. ex Ell.

This grass and several other common plumegrasses constitute a group of the largest, most conspicuous, upland grasses in the South. Bent-awn plumegrass grows throughout the Southeast, primarily on moist sandy soils of the longleaf-slash pine and loblolly-shortleaf pine types. Individual plants may reach 9 feet in height, but most are 6 feet or less.

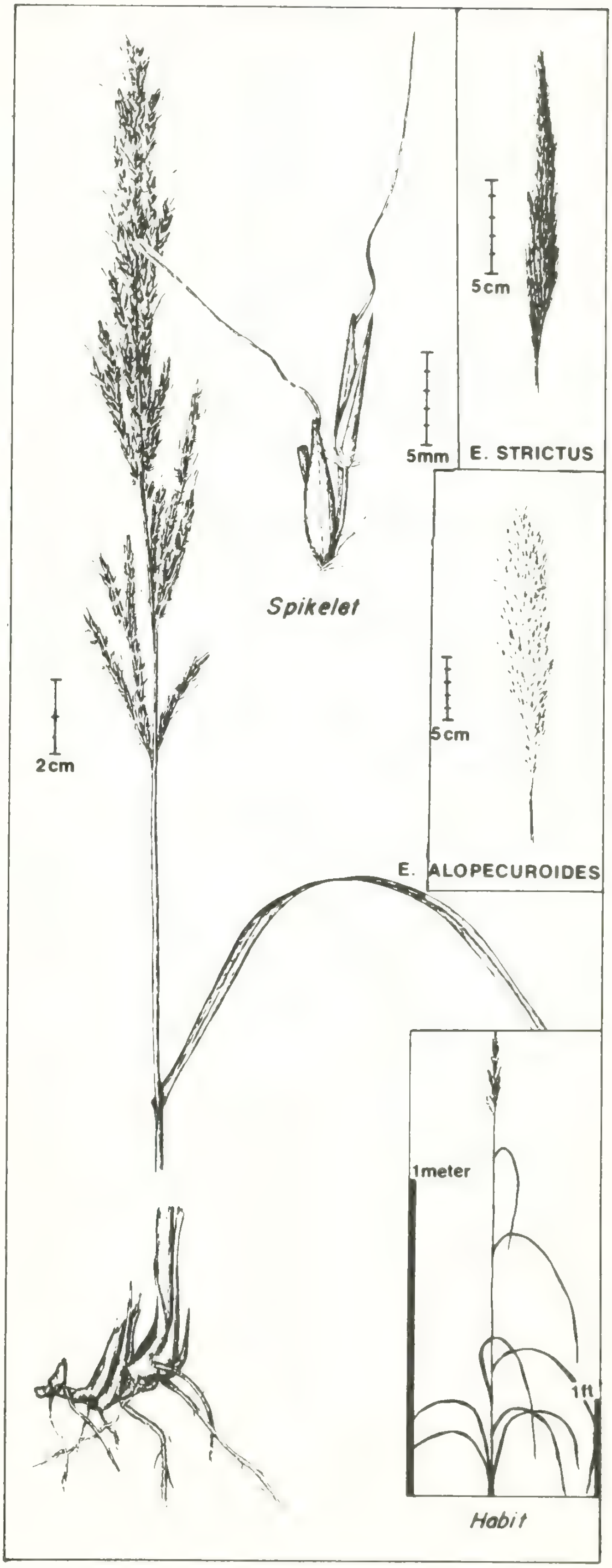
Until seed heads form, plants may be confused with yellow indiangrass; both have long, slender leaf blades, and bent-awn plumegrass has sheath auricles somewhat like those of indiangrass. However, the narrowed bases of indiangrass leaf blades and the purplish culms of plumegrass should distinguish the two.

The inflorescence, produced from midsummer to early autumn, is a loosely constricted panicle 5 to 15 inches long. Each brownish spikelet has a basal whorl of tawny hairs and a conspicuous, twisted awn. The arrangement of spikelets on inflorescence branches is similar to that in the bluestems. Pedicellate spikelets in the plumegrasses, however, are perfect; in the bluestems, pedicellate spikelets may be staminate but never perfect. Indiangrass seed heads, while outwardly similar to those of bent-awn plumegrass, have no pedicellate spikelets.

Other common plumegrasses include giant plumegrass, *Erianthus giganteus* (Walt.) Hubb. non Muhl., and silver plumegrass, *E. alopecuroides* (L.) Ell., which have denser, much silkier inflorescences; and narrow plumegrass, *E. strictus* Baldw., with a constricted, practically hairless, brown seed head. All are usually found on wetter sites than those occupied by bent-awn plumegrass.

A single plumegrass clump does not produce much foliage, and clumps are usually scattered. Early growth may be grazed by cattle and deer, but unless plants are grazed repeatedly, rapid growth renders plants tough and unpalatable by midsummer. As with big bluestem and other tall grasses, however, grazing intensity based on the total forage resource may weaken or kill plumegrass plants. Despite these limitations, plumegrasses as a group are classed as desirable forage plants.

Range: Texas and Oklahoma to Florida, Tennessee, and Maryland.



Perennial. **Culms** tufted, stout, erect, 1 – 2 m tall, glabrous or sparsely pubescent below panicle and at nodes; **sheaths** sparsely hirsute at throat; **ligule** 1 – 2 mm long, firm, minutely ciliate; **blade** 15 – 90 cm ong, 5 – 24 mm wide, flat or folded at the narrow base, densely hirsute on upper surface near ligule; **inflorescence** a purplish-brown, exserted panicle 12 – 42 cm long, 3 – 5 cm wide; **spikelets** all alike, 6 – 8 mm long, brownish, basal hairs as long as spikelet; **glumes** more or less hirsute on back and margins, second longer than first; **sterile lemma** shorter than glumes, pubescent; **lemma** 3 – 4 mm long, 2-toothed, hyaline, midnerve extended into scabrous awn 12 – 20 mm long.

Bearded Skeletongrass—*Gymnopogon ambiguus* (Michx.) BSP.

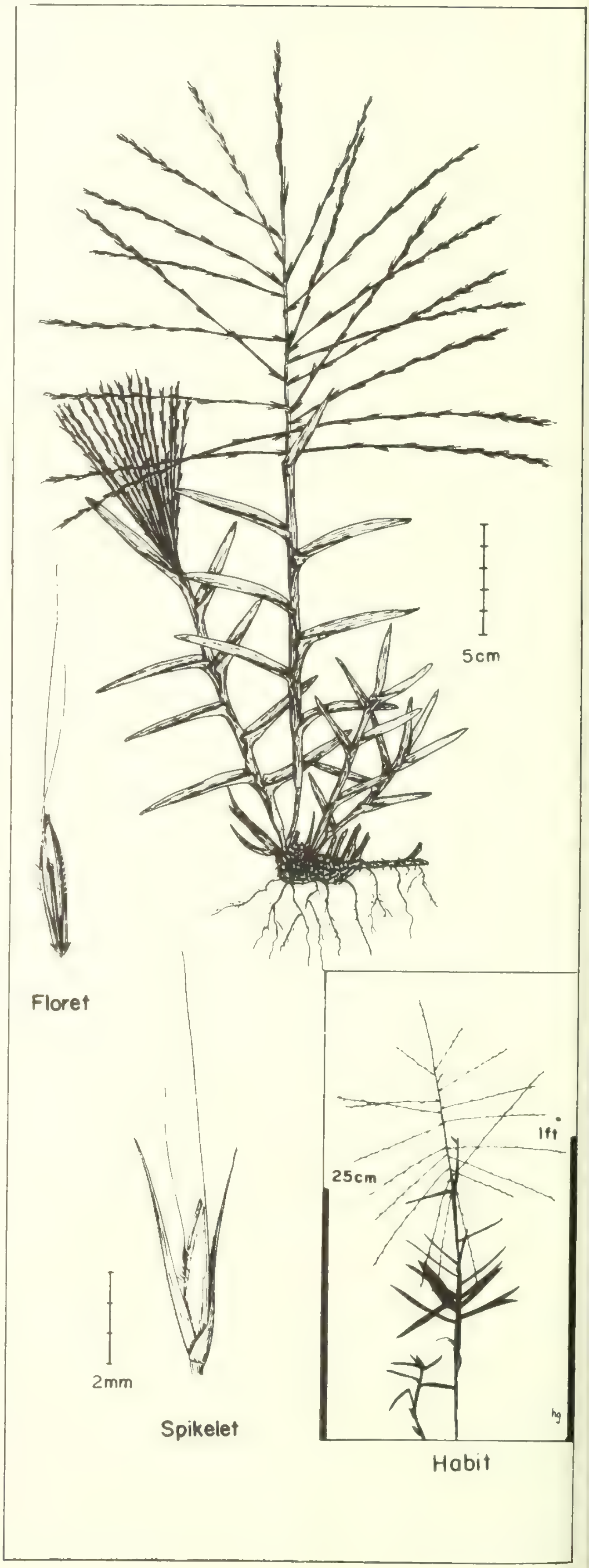
Bearded skeletongrass, though seldom abundant, is conspicuous on sandy pinelands in the South. Distinctive features include short, broad, stiff leaves and an inflorescence of many stiff, slender, divergent spikes scattered along the upper part of the flower stalk. At maturity, the seedstalk breaks below the lowermost spike, and the entire inflorescence becomes a "tumbleweed." Plants spread by short rhizomes to form small clumps. Basal foliage is scant; leaves are mostly crowded along the rigid stalks, which are 1 to 2 feet tall at maturity.

Although slim skeletongrass, *Gymnopogon brevifolius* Trin., is sometimes associated with bearded skeletongrass, it is also found on more mesic sites than commonly associated with bearded skeletongrass. It is distinguishable by its inflorescence branches, which have flowers only on the outer half; those of bearded skeletongrass bear flowers over their entire length.

Bearded skeletongrass rarely yields significant amounts of forage. Cattle apparently eat it, for plants are scarce on grazed range. The clumps are poorly anchored in the soil; thus cattle probably uproot many plants. Deer sometimes paw the rhizomes out of the soil in winter when better food is scarce.

Range: Texas to Florida, extending north to Kansas, Ohio, and New Jersey.

Perennial. **Culms** 30 – 60 cm tall, from short, scaly rhizomes, erect or decumbent at the base; **sheaths** crowded, overlapping with a villous ring at the summit, otherwise glabrous; **ligule** membranous; **blades** spreading, 5 – 15 cm long, 5 – 14 mm wide, flat, firm, cordate-lanceolate, glabrous with scabrous margins; **inflorescence** of numerous unbranched purplish spikes 10 – 20 cm long; **spikelets** 4 – 6 mm long, excluding the 6 mm awn, arranged the full length of the branch on two sides of a 3-sided rachis.



Cutover Muhly—*Muhlenbergia expansa* (DC.) Trin.

Cutover muhly grows throughout the lower Coastal Plain in swales and on moist pinelands. Although the name implies that it occupies only cutover lands, it is sometimes abundant under open pine stands. On unburned ranges, the long, stiff, slender leaves are in large, tightly tufted bunches, with blades near the perimeter of the bunch reclining and those near the center standing erect. The plants resemble grass-stage longleaf pines.

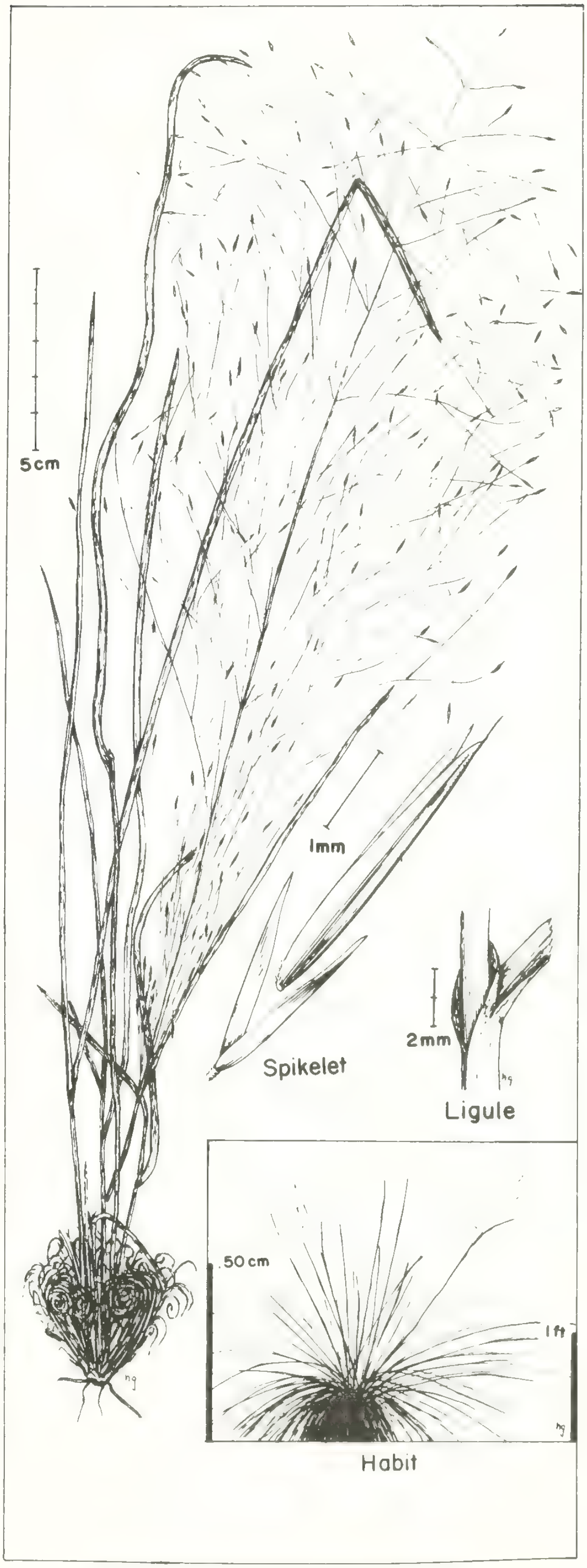
Flower stalks, 2 to 3 feet tall, are slender and weak, often reclining at maturity. Panicles are purplish, conical, and usually 6 inches long, but occasionally they reach 18 inches, and branches are delicate.

Hairawn muhly, *Muhlenbergia capillaris* (Lam.) Trin., is a similar and closely related grass with a wider range than cutover muhly. It is found on drier, more inland sites than cutover muhly. Some authors consider cutover muhly a Coastal Plain variant of hairawn muhly. Although its foliage resembles that of pineywoods dropseed, cutover muhly can be distinguished by its curly, fibrous remnants of old basal leaves. Its prominent, pointed, white ligules also help distinguish it from pineywoods dropseed, the ligule of which is barely visible.

Cutover muhly is low in forage value. Cattle ordinarily eat small amounts of new leaves in the spring, but they usually reject the foliage later in the growing season. Although mature leaves are tough and fibrous, some are eaten during the winter, because they often remain green. This species may impair production of better forage. On unburned, moderately grazed range, the plants attain large basal areas, and their leaves reach far beyond the basal perimeter. Thus, a comparatively sparse stand may dominate a site, excluding most plants of higher quality.

Because cutover muhly is generally considered a range weed, control has been studied. Although a single fire failed to kill plants in Louisiana trails, clump size was reduced. Where 30 to 40 percent of the range was burned each year in rotation, cattle concentrated on new burns in the spring. With the old growth destroyed by fire, cattle closely utilized new foliage. One cycle of burning and subsequent brief heavy use largely eliminated the species without significantly damaging the better grasses.

Range: Coastal Plain, east Texas to Florida and Virginia.



Perennial. **Culms** 60 – 100 cm tall, slender, erect, in dense tufts; **sheaths** longer than the internodes, wider than the blade, loose, smooth to slightly scabrous, weathering to form a fibrous, curling mass; **ligule** 2 – 3 mm long, wider than the blade, firm, pointed; **blades** 1.0 – 2.5 mm wide, to 40 cm long, the upper short, the lower long, flat, becoming involute; **panicles** 10 – 45 cm long, pyramidal, with capillary branches; **spikelets** 3.5 – 5.0 mm long, purple, on long, scabrous, capillary pedicels, awnless or with a short awn 2 – 3 mm long.

Knotroot Bristlegrass—*Setaria geniculata* (Lam.) Beauv.

Knotroot bristlegrass is common but seldom abundant along roadsides, in old fields and pastures, and on other disturbed sites throughout the South. It occurs infrequently on regularly burned, moderately grazed range. In Florida, however, it is a component of the stable plant community on flatwoods, slough, and salt marsh sites. Although a perennial, it produces little forage in competition with major forage plants like creeping bluestem.

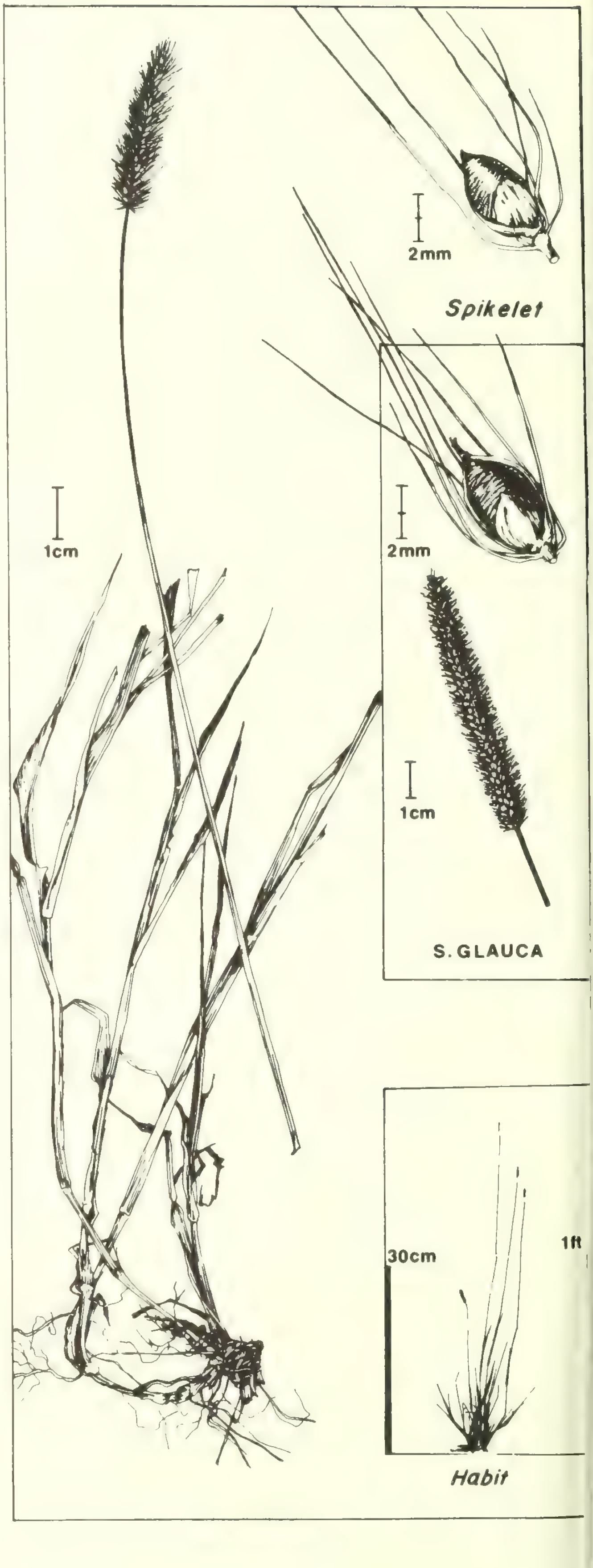
Plants are 2 to 3 feet tall, growing singly or in small tufts from brittle, knotty rhizomes. Stems are often geniculate, or bent at the lower joints, giving greater basal spread to the clumps. This characteristic is common to several other bristlegrasses as well as to some of the crabgrasses *(Digitaria* spp.). Leafblades are flat, about 1/5 inch wide and 2 to 9 inches long. Each seed stalk is terminated by a spikelike, bristly panicle ½ to 4 inches long.

A similar and equally common species, yellow bristlegrass, *Setaria glauca* (L.) Beauv. *(S. lutescens* (Weig.) F. T. Hubb.), is an annual introduced from Europe. Like knotroot bristlegrass, it has numerous bristles subtending each spikelet; bristles of most other bristlegrasses are generally longer and more cylindrical than those of knotroot. Leaf blades are wider in the annual species and rhizomes are present only in knotroot. Several other bristlegrasses occur in the Southeast, but knotroot is the only southern perennial.

Forage value of knotroot bristlegrass is limited by its lack of abundance. Even in Florida, where it is part of the "climax" vegetation, it produces scant herbage. It is grazed during spring and summer months but becomes unpalatable by fall. Knotroot bristlegrass is considered a food plant for birds and small mammals.

Range: California to Florida, extending north to Kansas, Illinois, and Massachusetts.

Perennial. **Culms** cespitose or single, 40 – 100 cm tall, often geniculate at base, erect or decumbent, often with short, knotty rhizomes; **blades** flat, strongly ascending, long-attenuate, 5 – 23 cm long, 4 – 7 mm wide, glabrous below, sparsely pilose above; **sheaths** glabrous with scarious margins; **ligule** membranous, short-ciliate; **inflorescence** a spiciform panicle, dense, yellowish to purplish, 1.5 – 10.0 cm long, 7 – 8 mm wide (excluding bristles); **spikelets** 2 – 3 mm long, subtended by 8 to 12 bristles, 2-flowered, the lower floret neuter, upper floret perfect; **first glume** one-half length of spikelet; **second glume** longer, with excurrent midrib; **sterile lemma** 5- to 7-nerved with well developed palea, fertile floret plano-convex 2 – 3 mm long; **lemma** transversely rugose.



Yellow Indiangrass—*Sorghastrum nutans* (L.) Nash—(*Sorghastrum avenaceum* (Michx.) Nash)

Although yellow indiangrass is best known as a component of tall-grass prairies, it occurs throughout the southern pine region. Plants are among the tallest grasses found on the range. Seedstalks average 4 to 5 feet but occasionally reach 8 feet. Foliage is mainly basal, with leaves up to 18 inches long and ½ inch wide. Plants spread by short, scaly rhizomes, often forming large clumps.

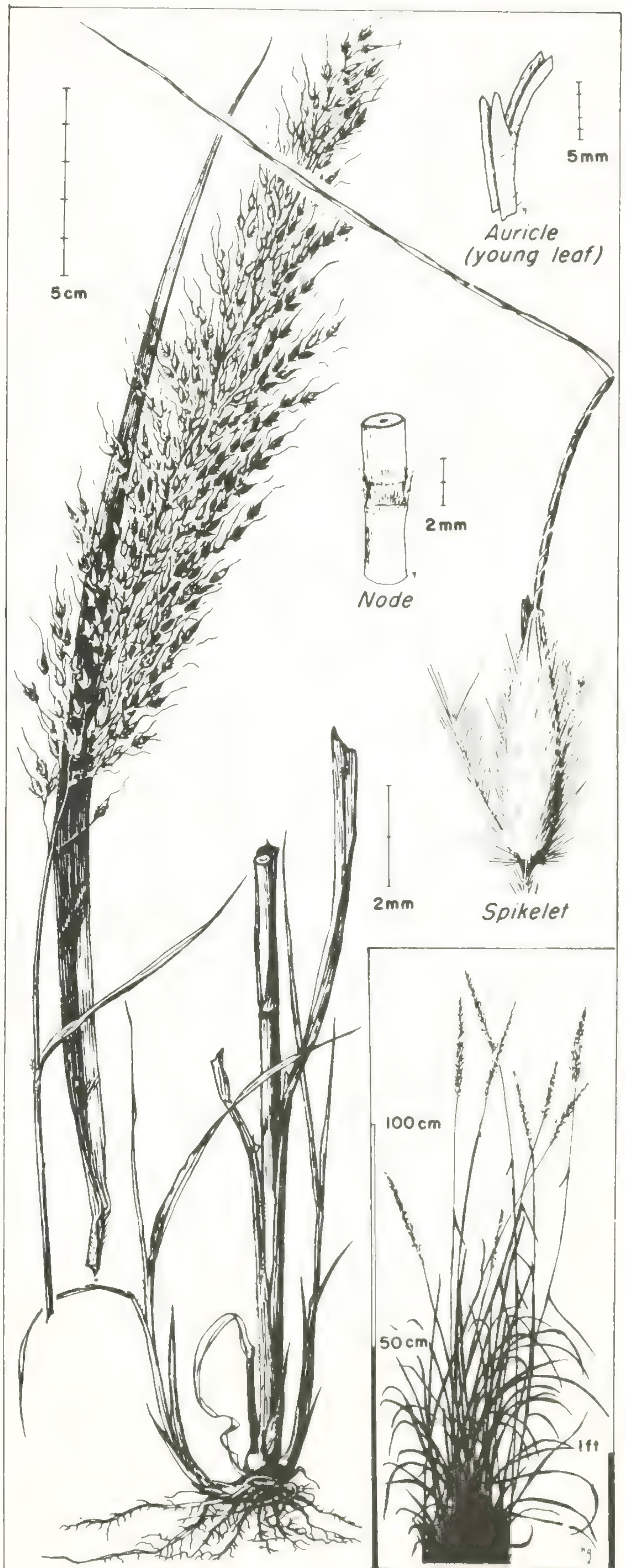
This grass produces large plumelike panicles, varying from bright yellow bronze to dark brown bronze. Panicles shatter quickly upon maturing; the plants remain showy only briefly, usually from late September to early October.

In the absence of panicles, yellow indiangrass superficially resembles switchgrass, big bluestem, and other robust grasses. Yellow indiangrass is distinguishable by its conspicuous, straight, stiff auricles and bristly nodes.

Two other *Sorghastrum* species growing on longleaf pine-bluestem range also closely resemble yellow indiangrass. Lopside indiangrass, *S. secundum* (Ell.) Nash, is common on sandhills of west Florida and south Georgia and in sandy pinelands of Alabama. As the name implies, its panicles, in contrast to the relatively symmetrical ones of yellow indiangrass, are one-sided. Slender indiangrass, *S. elliottii* (Mohr) Nash, grows throughout the South, mainly on sandy sites. Its flower stalks, in contrast to the relatively stiff ones of yellow indiangrass, are weak and nodding, and the spikelets are chestnut brown. Lopside and slender indiangrass lack rhizomes; both have twice-bent awns about 1 inch long, while awns of yellow indiangrass are bent once and are ½ to ¾ inch long.

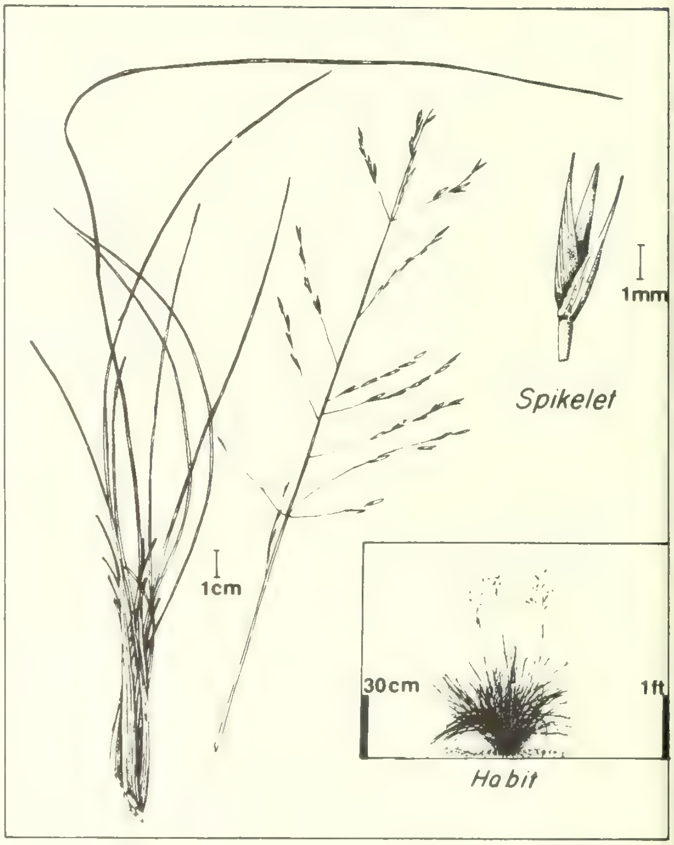
Yellow indiangrass is an excellent forage plant. Because it is highly palatable and scarce on most ranges, it is usually overgrazed, even under moderate use. On heavily grazed ranges, it is confined to brushy areas that cattle cannot readily penetrate. Managing for a high yield of this grass therefore appears impractical.

Range: Eastern United States, extending west to Arizona, Utah, Wyoming, and North Dakota.



Perennial. **Culms** glabrous with hairy nodes, 1.0 – 2.5 m tall, in loose tufts from scaly rhizomes; **sheaths** glabrous or papillose-pubescent, often hairy in the throat; **ligule** 2 – 4 mm long, thick, stiff, conspicuous, between straight, stiff auricles; **blades** 5 – 10 mm wide, sometimes glaucous, scabrous, elongate; **panicle** narrow, exserted, nodding at the apex, bronze to golden brown and shining, branches villous, shattering early; **sessile spikelet** fertile, 6 – 8 mm long, hirsute, the awn once-geniculate, 1.0 – 1.5 cm long; **pedicellate spikelet** wanting, the villous pedicel one-half to one-third the length of the fertile spikelet.

Curtiss Dropseed—*Sporobolus curtissii* (Vasey) Small



This small bunchgrass is found most commonly on southeastern pine flatwoods sites where it grows in close association with pineland threeawn. It grows as dense tufts or small bunches that remain partly green in winter. On pine-wiregrass range of south Georgia, Curtiss dropseed provides more cattle forage than any other grass during fall and winter but is grazed less than pineland threeawn during spring. Although it thrives on frequently burned range, it withstands smothering by litter in the absence of fire.

On closely grazed range, Curtiss dropseed may be mistaken for pineland threeawn; both have narrow leaves and grow in clumps. Leaf blades of Curtiss dropseed, though narrow, are flat, compared to the almost round blades of pineland threeawn. This distinction is noted in another common name for Curtiss dropseed, "flatleaf wiregrass."

Florida dropseed, *Sporobolus floridanus* Chapm., is a common associate of Curtiss dropseed and pineland threeawn on pine flatwoods. It is a more robust grass than Curtiss dropseed, with basal leaves about ¼ inch wide and up to 20 inches long. Stalks are up to 3 feet tall, with the narrow, open panicle occupying the upper half. Panicles are diffusely branched with a single spikelet at the top of each branch.

Range: Coastal Plain, central Florida to North Carolina.

Perennial. **Culms** slender, 30 – 70 cm tall; **sheaths** pilose at throat; **blades** light green, flat or folded, about 1 mm wide, pilose on the upper surface near the base; **panicle** pyramidal, 15 – 25 cm long, open, branches stiffly ascending; **spikelets** appressed along the branches, distant, bronze or purplish, about 4.5 mm long; **glumes** about equal, as long as or longer than lemma.

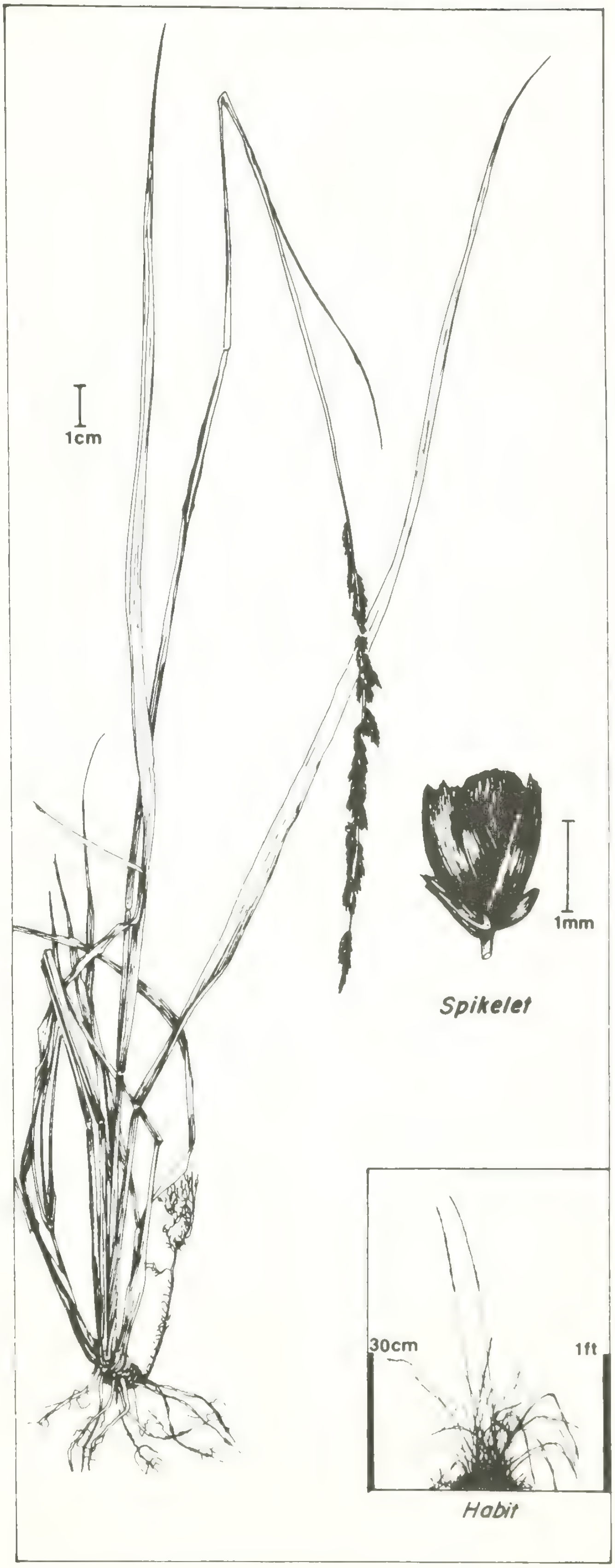
Rat- tail Smutgrass—*Sporobolus indicus* (L.) R. Br.—(*Sporobolus poirettii* (R. & S.) Hitchc.)

Smutgrass is a perennial grass common throughout the southern states, and can usually be identified by its long, narrow seed heads, which are often blackened by smut resulting from infection by the fungus, *Helminthosporium ravenelii* Curt. Introduced into the southern United States and South America from tropical Asia, smutgrass has become a serious weed of improved pastures in sandy Coastal Plains soils across the South. It is common along roadsides, trails, and in recreational areas, apparently thriving under adverse conditions.

Cattle seldom eat smutgrass, especially after the flower stalks are formed. Plants not infested with the black fungus produce abundant tiny seeds that are eaten by birds and small mammals.

Range: Texas and Oklahoma to Florida and Virginia.

Perennial. **Culms** erect, 30 – 100 cm tall, glabrous; **blades** 15 – 55 cm long, 1.5 – 3.0 mm wide; **sheaths** glabrous, longer than internodes, junction with blade obscure; **ligule** a ring of very short hair; **panicle** spikelike but interrupted, 10 – 40 cm long, 3 – 6 mm thick; **spikelets** 1.5 – 2.0 mm long; **seed** naked, reddish.



Pineywoods Dropseed—*Sporobolus junceus* (Michx.) Kunth

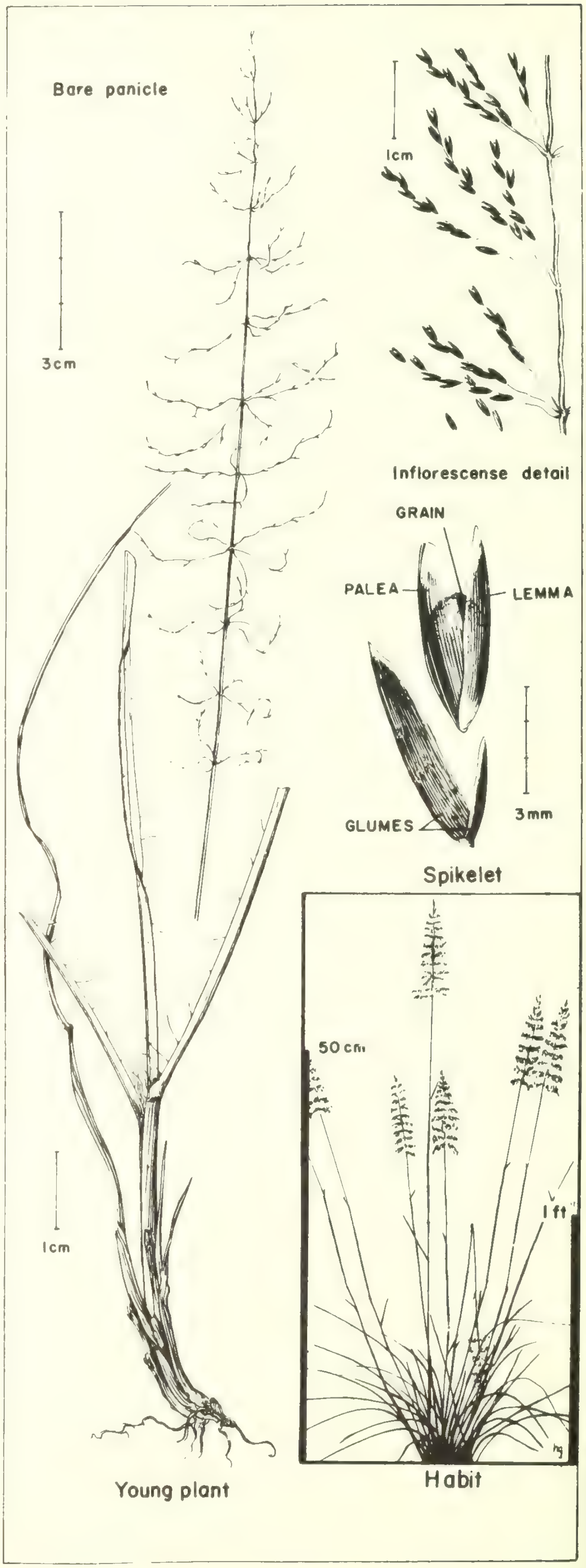
Pineywoods dropseed is a bunchgrass, with basal tufts arising from short, scaly rhizomes. In light herbaceous cover it may form large dense clumps. Where grass is dense, bunches are usually small, often consisting of only a few slender tufts. Foliage is mostly basal. Leaf blades are long, slender, blue green, and practically hairless. They often fold lengthwise, becoming almost tubelike in cross section. Thus, the leaves may superficially resemble longleaf pine needles. Flower stalks are 1 to 2 feet tall. They end in distinctive yellow- to brown-bronze, narrowly conical panicles that are usually 4 to 6 inches long and about one-third as wide.

Until inflorescences appear, pineywoods dropseed resembles cutover muhly. The latter is distinguishable by its prominent, white, pointed ligule, and by fragments of old basal foliage, which persist as a tangled mat of straw-colored fibers. The ligule in pineywoods dropseed is barely visible, and fibers of basal sheaths are nonpersistent.

Pineywoods dropseed rates fair as a forage grass. Its leaves become tough by midseason; thus, palatability is low during summer and fall. Herbage often remains green well into the winter. Although nutritive content is low during winter, cattle are attracted by the green color, and they may eat large amounts. On a Louisiana range where this species was only 1 percent of the ground cover, it provided 3 to 5 percent of the yearly diet. In January and February, it supplied about 10 percent of the grazing.

Range: Coastal Plain, Texas to Florida and Virginia.

Perennial. **Culms** 30 – 100 cm tall, erect, rigid, slender, in small clumps, leafy at the base, naked above, from short, scaly rhizomes; **sheaths** glabrous, strongly overlapping; **ligule** a smooth or ciliated short membrane; **blades** 2 – 4 mm wide, 2 – 25 cm long, folded or involute with a thickened, pointed apex, glabrous, base of lower blades with setaceous margins, the upper blades short and far below the panicle; **panicle** 2 – 5 cm wide, 10 – 20 cm long, lanceolate, with several sets of verticillate, spreading branches spaced at regular intervals; **spikelets** 2.5 – 3.5 mm long, acute, lanceolate, green, purple, or bronze in color; **glumes** of unequal length; **lemma** and **palea** thin, free from the seed; **seed** ovoid, brown, 1.5 – 2.0 mm long.



Pinebarren Tridens—*Tridens ambiguus* (Ell.) Schult.

Pinebarren tridens grows on moist flatwoods sites, particularly where moderate to heavy grazing prevents accumulation of a heavy rough. It is commonly associated with slender bluestem, both on cutover lands and under open pine canopies.

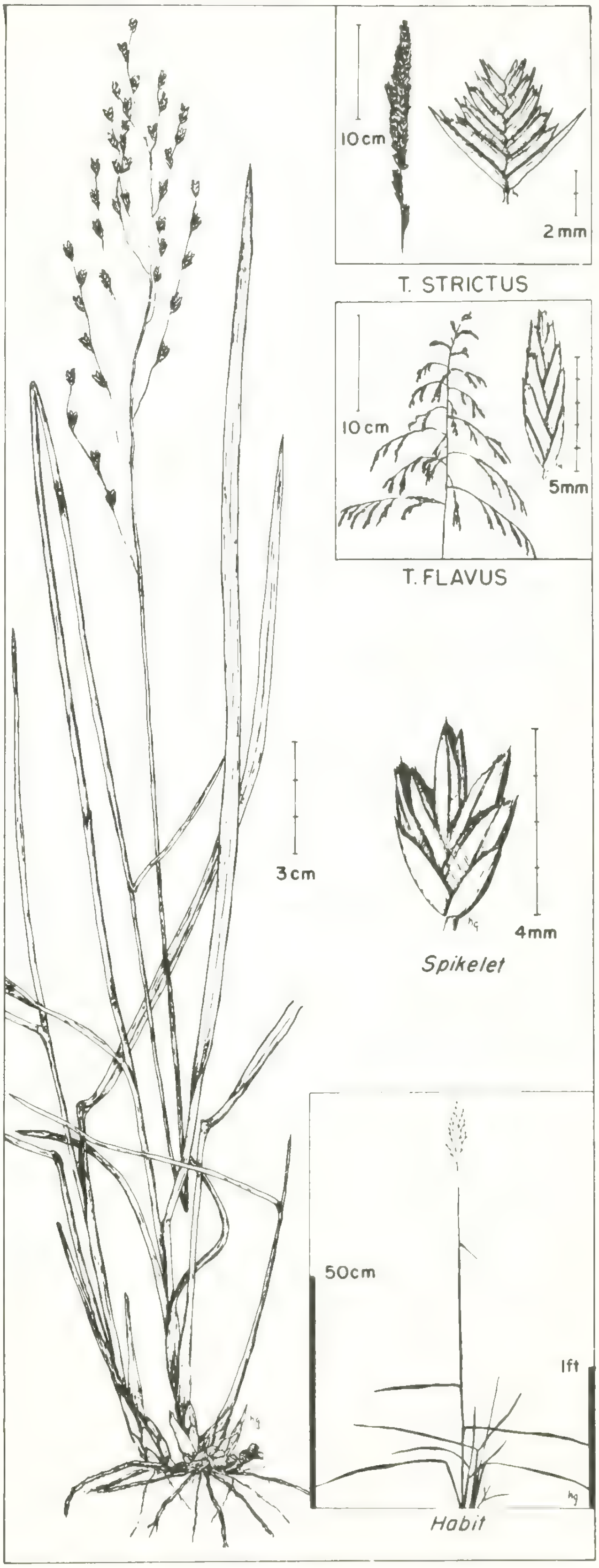
Leaves are mostly basal, usually with one or two small tufts per plant. They are generally pale green, but the upper surface is sometimes gray-green. Blades are about ⅛ inch wide and up to 12 inches long. Except for conspicuously hairy leaf collars, the foliage is hairless. Flower stalks 2 to 3 feet tall support open panicles that bear small, orange-tan to purplish spikelets. Panicle branches characteristically point upward at an angle of less than 45° from the main axis. Spikelets measure ⅙ to ⅜ inch long, each with four to seven flowers. Spikelets are round in cross section when immature but become flattened with age.

Pinebarren and other tridens grasses may be mistaken for lovegrasses *(Eragrostis* spp.) because of the several-flowered, flattened spikelets. The genus *Tridens* is characterized by lemmas with three hairy nerves that project beyond the margin of the lemma tip, while the lemma of *Eragrostis* has hairless nerves which do not extend past the margin.

Several species of *Tridens* grow on southern pine ranges. Purpletop, *T. flavus* (L.) Hitchc., is a robust perennial occupying old fields and timbered sites. It is distinguishable by its large panicles with drooping branches and dark purple spikelets. Longspike tridens, *T. strictus* (Nutt.) Nash, inhabits wet sites. Its dense, spikelike panicle differs distinctly from the open inflorescence of other common tridens grasses. Also, its spikelets have glumes longer than the lowest florets. Carolina tridens, *T. carolinianus* (Steud.) Henr., is a rhizomatous species, infrequent on moist sandy sites, with an inflorescence similar to that of pinebarren tridens. In both, mature spikelets are slightly flattened in cross section and ¼ inch or more long.

Young foliage of pinebarren tridens is grazed in the spring and early summer. Because plants are widely scattered and foliage is sparse, this species contributes little to the yearly diet of cattle. After the panicles emerge, plants are grazed sparingly, if at all. The spikelets emit a distinctive pungent odor that may account for the low palatability of mature plants.

Range: Coastal Plain, Texas to Florida and South Carolina.



Perennial. **Culms** 60 – 100 cm tall, from a knotted base, slender, erect; **sheath** flattened, shorter than the internodes, glabrous; **ligule** a conspicuous ring of hairs; **blades** pointed, flat or slightly involute, the upper short, the lower long, but not exceeding the extended panicle; **inflorescence** a loose, tan or purplish panicle 8 – 20 cm long with ascending branches; **spikelets** 4 – 6 mm long, 3 – 4 mm wide, 4- to 7-flowered, flattened; **florets** conspicuously pilose on the lower half; **lemma** with three prominent veins forming short teeth at the apex; **palea** with a conspicuously bowed keel.

GRASSLIKE PLANTS

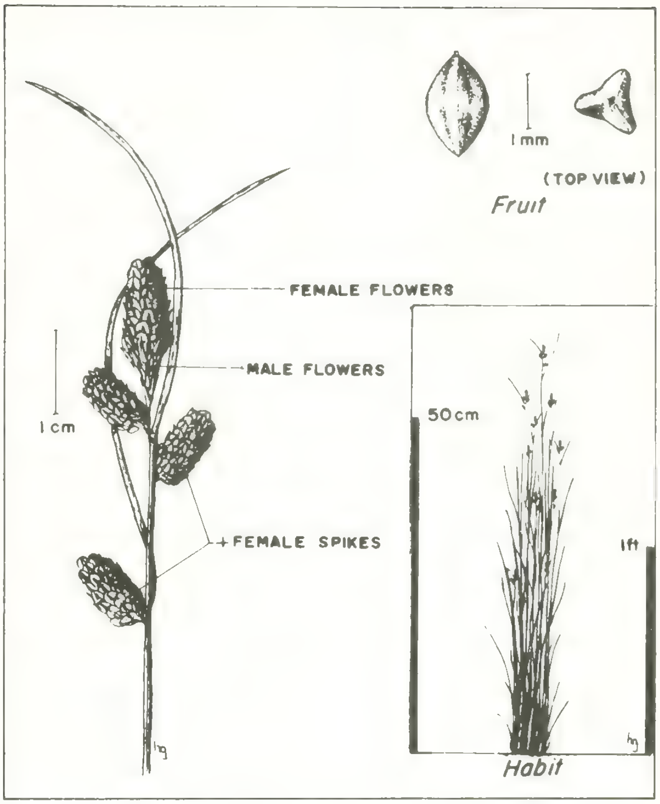
Because they superficially resemble grasses, members of the sedge family (Cyperaceae) and rush family (Juncaceae) are known as grasslike plants. They are a minor part of the vegetation on most upland pine forest sites, but several species grow abundantly on poorly drained soils.

The sedges most closely resemble grasses; both the sedge and grass families belong to the order Graminales. Their flowers are in spikelets and lack regular sepals and petals, each flower being subtended by bracts or scales. In most sedges, the stems are solid and triangular in cross section, with leaves three-ranked; grass stems are more or less cylindrical and leaves are in two ranks. Sheaths of sedge leaves are closed tubes that encase the stem. In all but a few grasses, sheaths are open. A minor technical difference distinguishes the one-seeded sedge fruit, an achene, from the grass fruit, a caryopsis.

Rushes are related more closely to lilies than to the grasses. Despite their morphological similarity to lily flowers, rush flowers appear grasslike, with sepals and petals that are small and chaffy or membranous. Although flowers may occur in dense heads, or glomerules, each is a separate unit with three sepals, three petals, and reproductive parts. The fruit is a capsule with many seeds. Stems may be rounded or flattened and pithy or hollow. Unlike grass stems, rush stems are not jointed. Rush leaves are mostly basal and not distinctly two- or three-ranked, as in grasses and sedges.

Grasslike plants are important in the cattle diet only on wet sites. Forage value is generally inferior to that of grasses. Cattle graze both rushes and sedges in spring and early summer but usually avoid them in late summer and fall. Since the plants often remain green well into the winter, cattle may again seek them after frost kills back other herbage.

Blue Sedge—*Carex complanata* Torr. & Hook.



Blue sedge plants are stiffly erect and 3 feet tall or less. They form many-stemmed clumps from knotty rootstocks, growing mostly on upland sites in association with bluestem and panicum grasses.

Flowers are unisexual, with male flowers found only basally on the uppermost spike; the remainder of this spike is comprised of female flowers. The uppermost spike is the only mixed spike; spikes below this are made up of only female flowers, and usually there are no more than four of these female-only spikes. The spikes are densely flowered, ¼ to 1 inch long, and about ¼ inch wide. Bracts subtending each flower give the spikes a bristly appearance. The sac (perigynium) enclosing individual female flowers is flattened, with obtuse or rounded tips.

Leaves are stiff and erect, with blades about $^{1}/_{16}$ inch wide. Although a few hairs are scattered on the leaf sheaths, plants generally appear smooth and hairless. Basal sheaths are purplish or reddish brown. Leaves seldom exceed the inflorescence, but one or two leaflike bracts may surpass the upper spike.

Although plants are often numerous, they produce little herbage. Hence, blue sedge seldom contributes significantly to the cattle diet.

Frank sedge, *Carex frankii* Kunth, on moist hardwoods sites, and southern sedge, *C. glaucescens* Ell., on pine-hardwoods uplands, are common throughout the South. Both have leaf blades ¼ to ½ inch wide. Blades of southern sedge have a gray-green upper surface; this coloration is lacking in Frank sedge. Southern sedge is the taller of the two, but both may exceed 2 feet in height.

Range: Texas, Oklahoma, and Missouri to Georgia and Pennsylvania.

Perennial. **Stems** 30 – 120 cm tall, stiff, erect, usually in small dense clumps from short, knotty rhizomes; **leaves** stiffly ascending; **blades** 2 – 4 mm wide, elongate; **basal sheaths** purplish to brownish red, older sheaths becoming fibrous at base of stem; **inflorescence** of two to five spikes, the terminal spike staminate at base, pistillate above; other spikes pistillate; spikes 8 – 15 mm long, 5 – 7 mm thick, the terminal spike usually longest; **flowers** subtended by lanceolate, scarious-margined bracts; **staminate flowers** with three stamens; **pistillate flowers** with an ovary enclosed in a beakless, flattened, ovoid perigynium about 2 mm long; **fruit** an achene 1.5 – 2.0 mm long, triangular in dorsal outline, acute-ellipsoid in lateral outline.

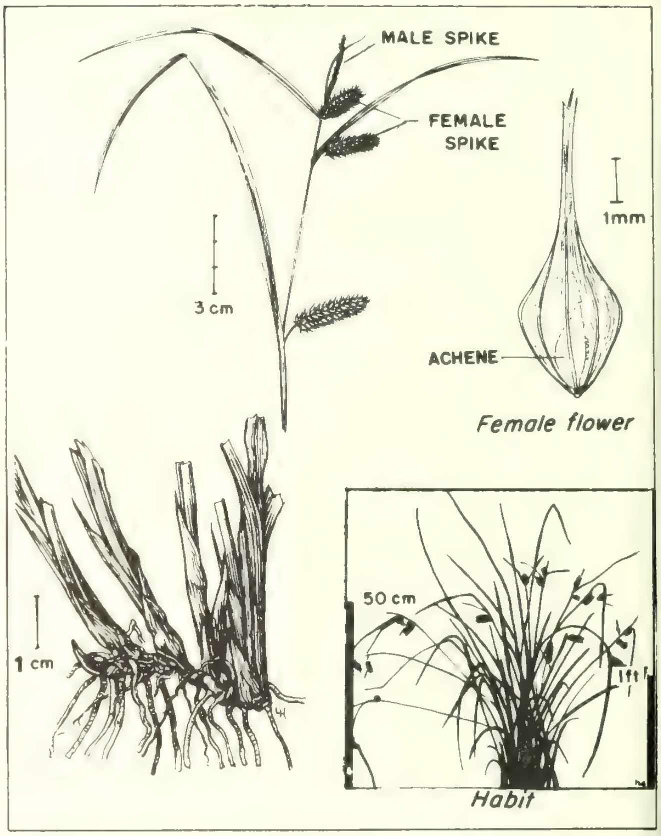
Lurid Sedge—*Carex lurida* Wahl.

Lurid sedge grows 1 to 3 feet tall in wet woods or swampy sites, forming dense clumps from stout scaly rhizomes. The inflorescence consists of two to five spikes, the uppermost with male flowers and those below with female flowers. Both male and female spikes are ½ to 3 inches long. Male spikes are only about ⅛ inch in diameter, while the female spikes exceed ½ inch. Flowers appear early in spring, the spikes persisting through the growing season.

Leaves are about ¼ inch wide and 15 inches long. Stems are leafy throughout. The upper leaves, as well as the leaflike bract below the inflorescence, usually exceed the inflorescence in height. Leaf blades are yellow green; basal parts of the lowest leaf sheaths are purplish.

Individual clumps of lurid sedge produce as much herbage as many of the grasses. Because plants are seldom abundant, except on very wet sites, this species is not important for forage.

Range: Texas to Florida, extending north to Canada.



Perennial. **Stems** glabrous, 20 – 100 cm tall, in dense clumps from short, stout rhizomes, usually bending somewhat under the weight of the spikes; **leaves** 2 – 7 mm wide, 30 – 40 cm long, pale green or yellow green, glabrous, upper leaves exceeding inflorescence; **inflorescence** a terminal staminate spike with one to four pistillate spikes below; **staminate spikes** 1 – 7 cm long and 2 – 3 mm thick; **pistillate** spikes burlike, 1 – 7 cm long, 1.5 – 2.0 cm thick; **individual flowers** subtended by lanceolate bracts; **staminate flowers** with three stamens; **pistillate flowers** with ovary enclosed in ovoid, beaked perigynium 6 – 9 mm long, 2.5 – 3.0 mm thick; **fruit** an obovoid, 3-angled achene 2.0 – 2.5 mm long.

Green Flatsedge—*Cyperus virens* Michx.

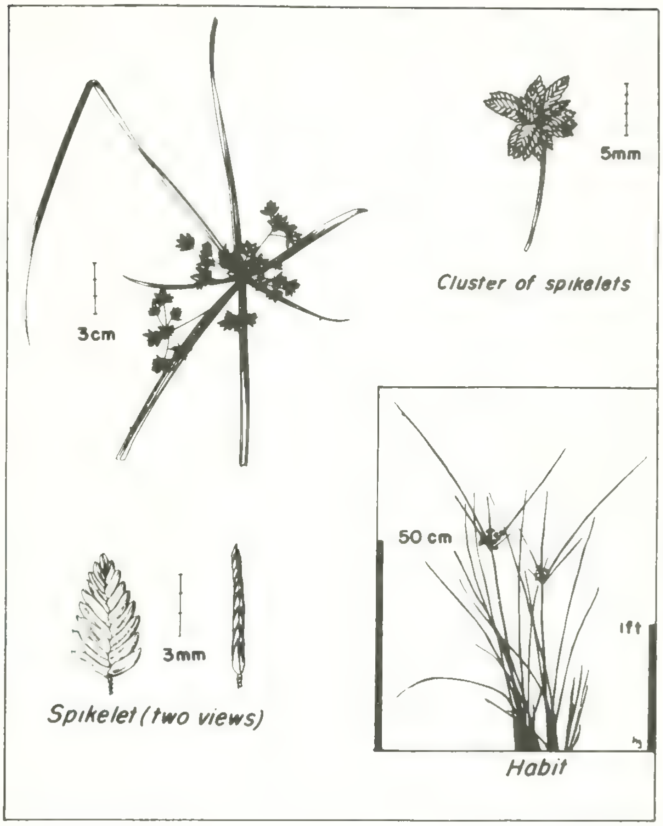
Green flatsedge often grows in small colonies on wet sites and in small low areas on otherwise well-drained soils. Plants spread vigorously from long, thick rhizomes, normally reaching about 2 feet in height but sometimes exceeding 3 feet.

As in all *Cyperus* species, a whorl of leafy bracts subtends the green flatsedge inflorescence, exceeding it in height. In the immature inflorescence, flatness of the individual spikelets is obscured by the density of the clusters. As the spikelets develop, however, new flowers form at the tips, and the lower, mature flowers fall. Thus, by midsummer the inflorescence consists of loose clusters of distinctly flat spikelets borne on naked stalks. Mature spikelets are about ⅛ inch wide and less than 1/32 inch thick. Spikelet length depends on maturity, ranging from about ¼ inch in young inflorescences to ½ inch at maturity. Each flower of the spikelet produces a straight, narrow achene about 1/16 inch long.

Leaves are all basal. They are about ¼ inch wide at the base, abruptly narrowing to about ⅛ inch, then tapering gradually to a fine point. Blades ascend stiffly, reaching 2 feet or more in length. Near their bases, leaves are loosely coated with a mat of fine hairs; otherwise, plants are hairless. Small warty lumps often appear between veins of the blades, giving the leaves a knotty appearance.

Although green flatsedge is common, it is unimportant as forage. The foliage is not readily eaten by cattle, and the seed apparently has little value for wildlife.

Range: Texas to Florida, extending north to Kansas, Missouri, Illinois, and New Jersey.



Perennial. **Scapes** to 1 m tall, forming clumps or colonies from stout rhizomes; **leaves** basal, ascending, elongate, usually exceeding the inflorescence, the base 4 – 7 mm wide and woolly-pubescent; **blade** glabrous on upper surface, 1 – 2 mm wide, gradually narrowing to tip; **inflorescence** an umbel of spikelet clusters, subtended by an involucre of leaflike bracts, peduncles unequal in length; **spikelets** 3 – 4 mm wide, up to 14 mm long; **fruit** a linear achene up to 1 mm in length.

Annual Spikesedge—*Eleocharis microcarpa* Torr.

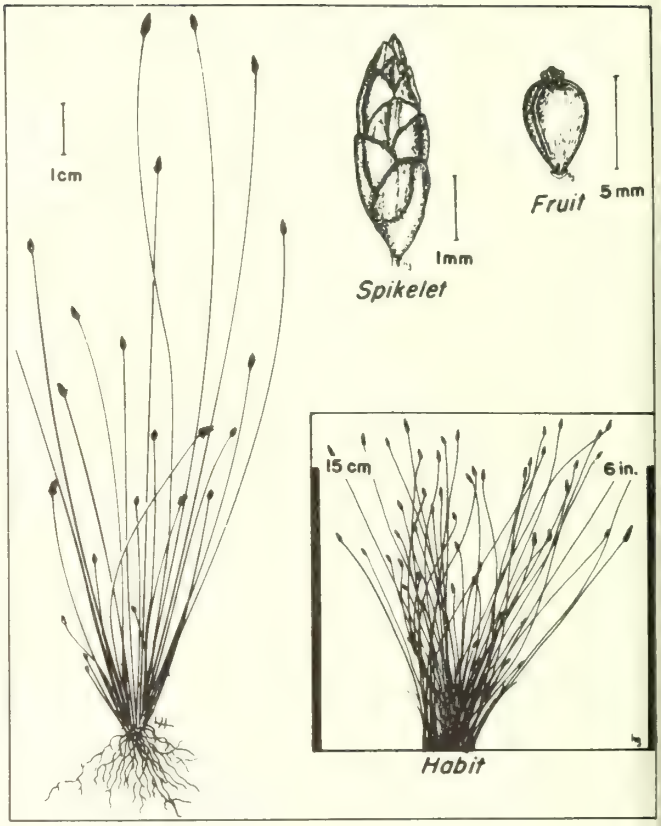
Annual spikesedge inhabits wet meadows and swampy areas. It grows in small clumps with many hairlike flower stalks averaging 6 inches high. Each stalk ends in a single ovoid, several-flowered spikelet about ⅛ inch long. Spikelet scales are pale with a papery texture. The inconspicuous basal leaves resemble the flower stalks but are usally shorter.

The fruits are barely visible to the naked eye. With magnification, they appear ovate in outline. They are three-angled in cross section, with prominent ribs. The persistent base of the style forms a green cap (tubercle) at the apex.

Flowers appear in spring and seeds mature in early summer. Seeds germinate in late winter, and plants begin growth before most grasses. Cattle may graze this early herbage; otherwise annual spikesedge has little forage value.

Another annual, conecap spikesedge, *Eleocharis tuberculosa* (Michx.) R. & S., resembles annual spikesedge in size and general appearance, but is distinguishable by its large tubercle, which equals the seed in size. Hairsedge, *Bulbostylis capillaris* (L.) C. B. Clarke, another small fine-stemmed annual, is recognizable by its cluster of brown ovoid spikelets at the branch tips.

Range: Coastal Plain, Louisiana to Florida and Virginia.



Annual. **Stems** slender, 4-angled, 5 – 30 cm tall, in small, many-stemmed tufts; **leaves** reduced to slender basal sheaths around the flower stalks; **inflorescence** a terminal spikelet, lanceolate to oblong or ovate, 2 – 7 mm long, 1.0 – 1.5 mm thick, several-flowered, lower flowers falling when mature; **flowers** enclosed by scarious-margined scales; **fruit** a 3-angled, obovoid achene, 0.5 mm in diameter with a minute warty tubercle at the top.

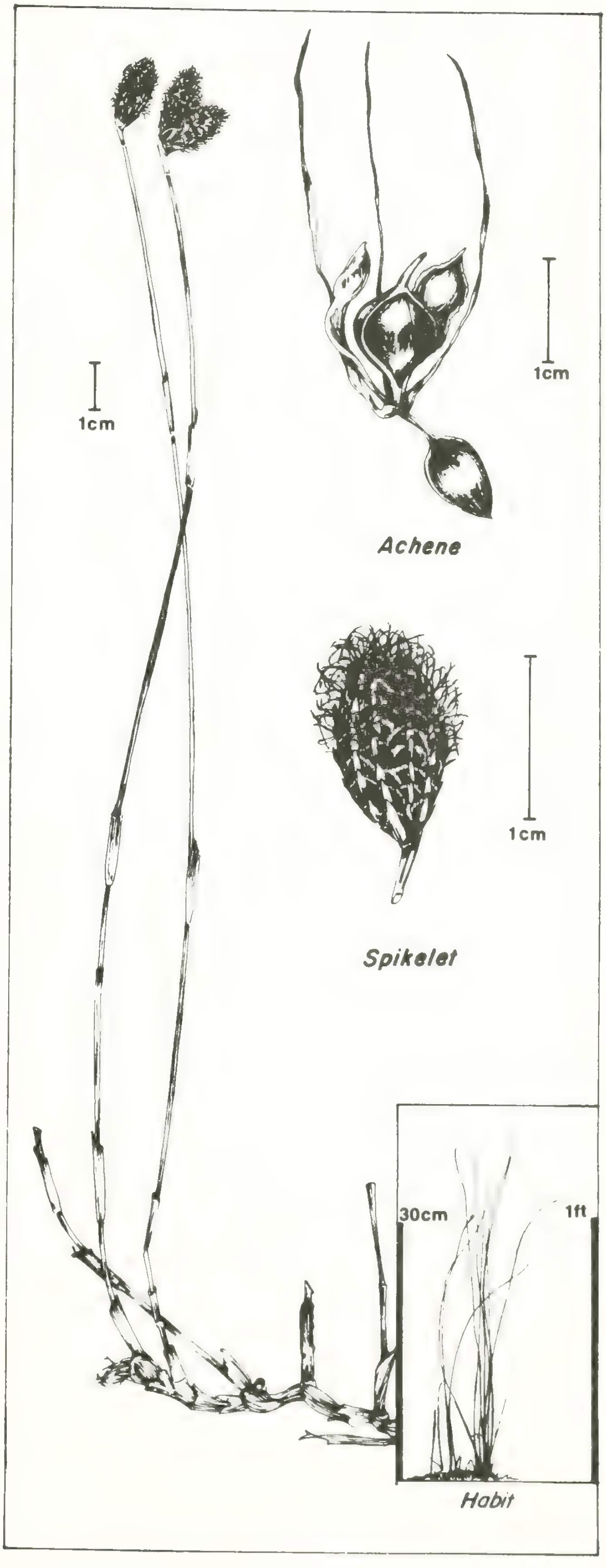
Common Umbrella-Grass—*Fuirena scirpoidea* Michx.

Common umbrella-grass, or umbrella-sedge, is a perennial sedge found on lake shores, low pinelands, and fresh water marshes of the Coastal Plain. Stalks about 1 foot tall arise in early spring from slender rootstocks, usually forming colonies. Stalks are unbranched and leaves are few and reduced to sheaths only. From one to four bristly spikelets terminate each stalk. Hairy umbrella-grass, *Fuirena squarrosa* Michx., occurs southwide in ditches and marshes. It is hairy, not strongly rhizomatous, and, unlike common umbrella-grass, has leaf blades.

Although cattle graze the young growth of common umbrella-grass readily, the scant foliage provides little forage for grazing animals.

Range: Coastal Plain, Louisiana to Florida and Georgia.

Perennial. **Stems** 20 – 60 cm tall, unbranched, rhizomatous; **leaves** reduced to sheaths only, with oblique margins; **spikelets** solitary or in clusters of two to four, 8 – 12 mm long, scales pubescent, 3 – 4 mm long with a short subulate tip, blades of the perianth scales ovate, about 1 mm long rounded at base; **fruit** an oval-rhombic or somewhat obovoid achene, about 1 mm long.



Pinehill Beakrush—*Rhynchospora globularis* (Chapm.) Small

Pinehill beakrush may be the most common sedge on southern pine-bluestem range. It grows most abundantly on poorly drained flatwoods or other wet sites but is also a common associate of bluestem grasses on drier soils. Its brown seed heads often dominate the landscape in late spring or early summer before most grasses produce seedstalks.

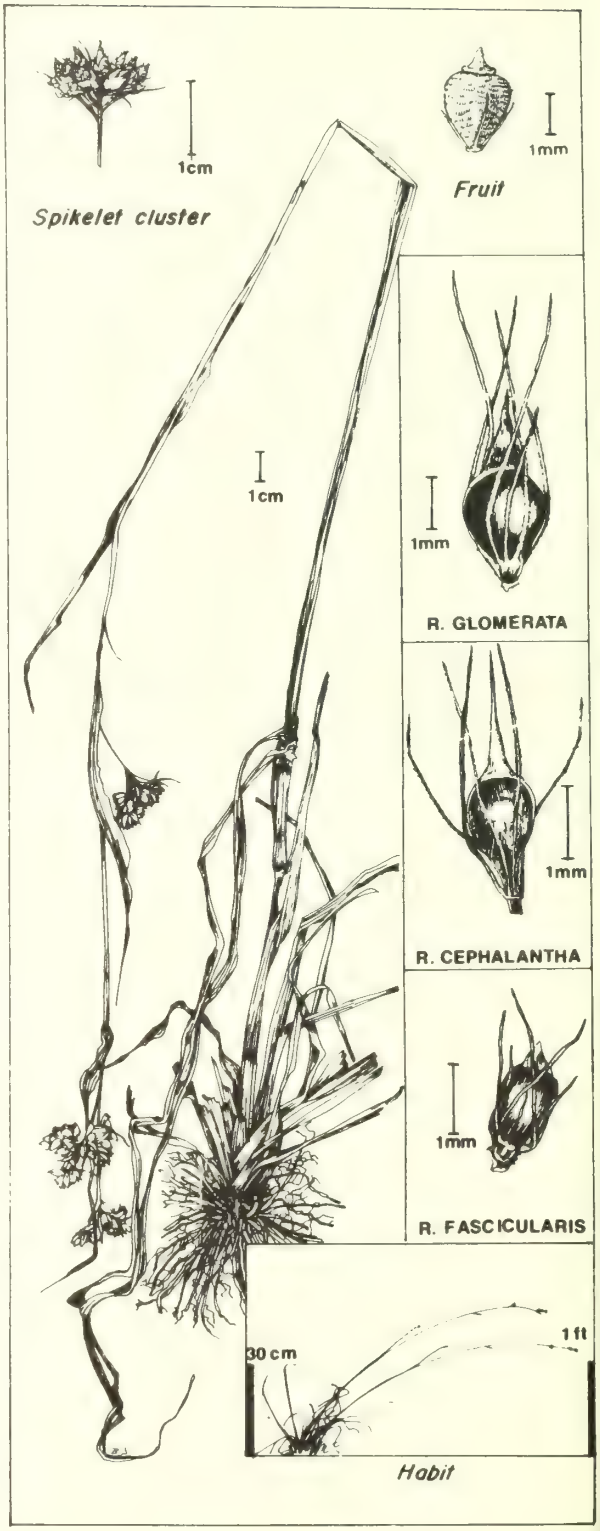
Plants grow in small tufts with erect basal leaves 4 to 12 inches long and 1/16 to 1/8 inch wide. There are one to several seedstalks per plant, and the range in height is from 6 inches to over 3 feet. Leaves are mainly basal, but a few reduced leaves are borne on the stalk up to the base of the inflorescence. Stalks, erect when young, recline as plants mature.

The inflorescence consists of spikelet clusters on branches arising from the axils of upper leaves. Each branch divides into a compound head, with each branchlet supporting a compact cluster of spikelets. Although a spikelet has several flowers, seldom will more than one fruit mature. Spikelets are rusty brown and about 1/8 inch long. The fruit, about 1/16 inch long, is a hard, oval, wrinkled achene, slightly flattened, with the remnant of the style forming a pointed cap or "beak." A whorl of bristles, somewhat shorter than the fruit, arises from the base of the achene.

On some sites, pinehill beakrush provides up to 3 percent of the annual cattle diet. Beakrush seeds are considered good quail food.

Other common beakrushes on southern pine range are cluster beakrush, *Rhynchospora glomerata* (L.) Vahl, common beakrush, *R. fascicularis* (Michx.) Vahl, and big beakrush, *R. cephalantha* Gray. All are widely distributed in the Gulf and Atlantic Coastal Plains, where they are found on wet or moist sandy sites. They can be separated from pinehill beakrush and from each other by glomerule and spikelet characteristics as shown in the accompanying illustrations. Nodding beakrush, *R. inexpansa* (Michx.) Vahl, another common species across the South, has spikelets in loose, nodding clusters. Horned beakrush, *R. corniculata* (Lam.) Gray, is a common large plant growing in ditches or other wet sites. The inflorescence is profusely branched, with few spikelets in each of numerous clusters. The brown spikelets are narrow, tapering to a bristle-tipped apex. The fruit has a beak that is commonly longer than the body of the fruit.

Range: Coastal Plain, New Jersey to Florida and east Texas, extending inland to Tennessee, Missouri, and Oklahoma.



Perennial. **Culms** glabrous, to 1 m tall, reclining as flowers mature; **leaves** glabrous, mainly basal, 2 – 5 mm wide, up to 35 cm long; cauline leaves reduced, the uppermost bractlike, subtending and exceeding inflorescence branches; **inflorescence** a terminal cyme and one to six lateral, often distant, cymes; **cymes** 1.0 – 3.5 cm in diameter, branches terminating in glomerules of many crowded spikelets; **spikelets** 2.5 – 4.0 mm long, broadly ovoid to subrotund, several-flowered but maturing only one or two fruits **fruit** an achene, 1.3 – 1.6 mm long, 1.2 – 1.5 mm wide **tubercle** 0.3 – 0.6 mm high, deltoid-conical; **bristles** one-half to three-fourths as long as achene.

Fringed Razorsedge—*Scleria ciliata* Michx.

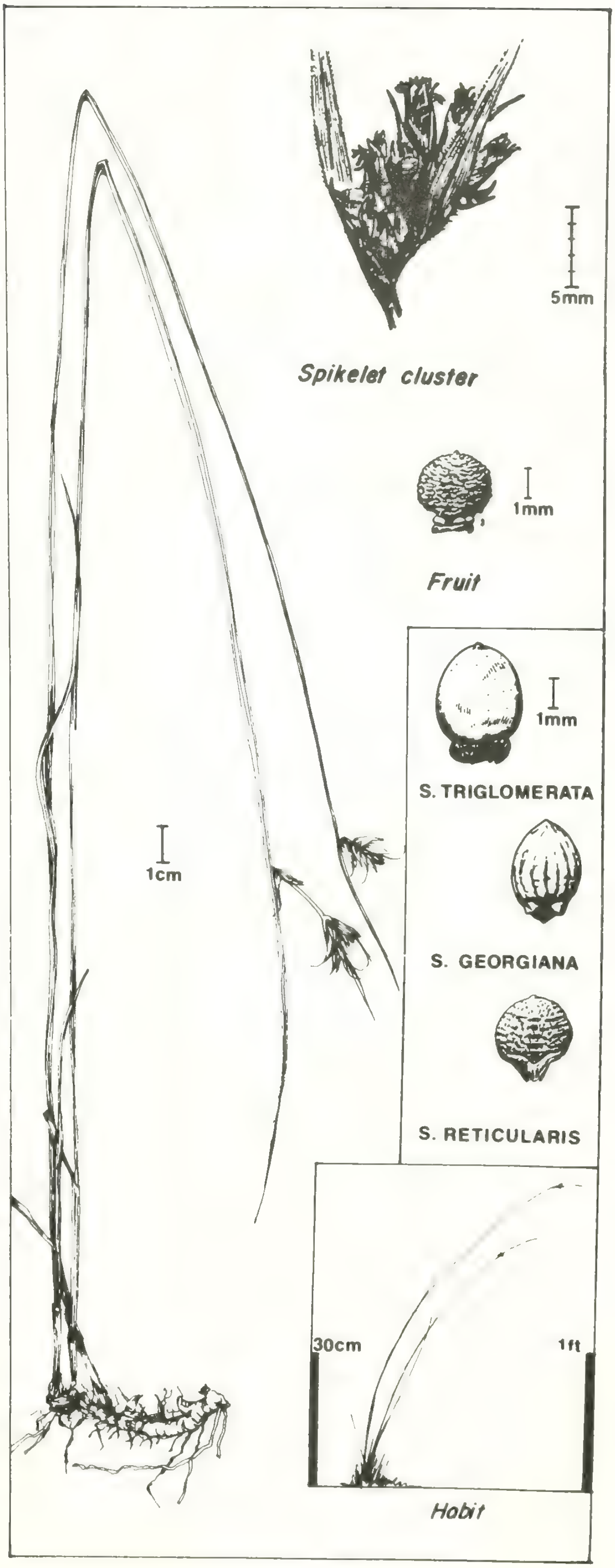
Fringed razorsedge is a common but seldom abundant sedge found on sandy pinelands of the Coastal Plain. It is a perennial, with stems 10 to 25 inches long arising from knotty rhizomes, nodding at maturity under the weight of the terminal inflorescence. Stems are triangular with several leaves arising from the base and lower half of the stem. The inflorescence consists of one to three clusters of spikelets; clusters may consist of staminate or pistillate flowers, or both. The white, bony, naked fruit is a distinguishing characteristic of the razorsedges. The fruit of fringed razorsedge is globose, about $^{1}/_{16}$ inch in diameter, and roughened with bony ridges.

Other razorsedges with wide distribution in coastal states are little razorsedge, *Scleria georgiana* Core, whip razorsedge, *S. triglomerata* Michx., and annual razorsedge, *S. reticularis* Michaux. Vegetatively, these other razorsedges resemble fringed razorsedge, although sizes vary. Little razorsedge is similar in size, but the fruits are smooth with longitudinal ridges; viable fruits are dark and sterile fruit are white. Whip and annual razorsedges are more robust plants. Fruits of whip razorsedge are smooth, shiny, and bright white; those of annual razorsedge may be hairy.

Razorsedge fruits are generally classed as desirable food for quail, doves, and other birds. Fringed razorsedge fruit is considered an important quail food across the South. Annual razorsedge fruit is a preferred food of bobwhite quail and mourning doves in southern Florida. Plants of all species are generally too sparse to be valuable as forage for deer or livestock.

Range: Texas and Missouri, extending east to Florida and Virginia.

Perennial. **Culms** tufted, from knotty rhizomes, 3-angled, 30 – 60 cm long; **leaves** glabrous or pubescent, to 20 cm long, 1 – 7 mm wide; **inflorescence** of two to three terminal or axillary cymes, each with few spikelets 1 – 3 cm long; **spikelets** unisexual, few-flowered; **achenes** globose, white, verrucose, 2 – 3 mm in diameter.



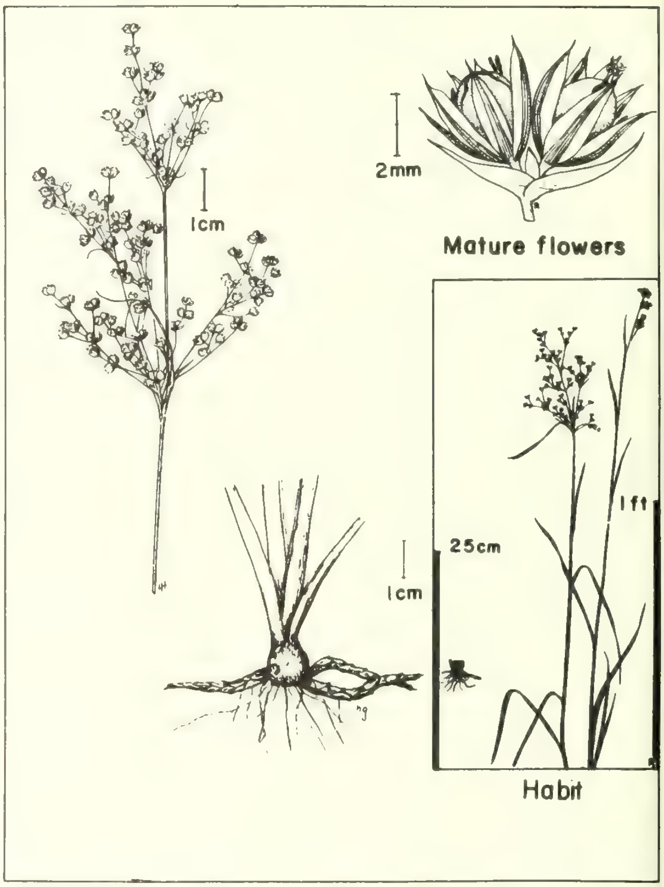
Twinflower Rush—*Juncus biflorus* Ell.—(included with *J. marginatus* Rostk. by some recent authors)

Although not abundant, twinflower rush is conspicuous at maturity because of its tall flower stalks and large brown seed heads. It grows mainly in ditches, along shores, or in other low, wet, usually sandy, open sites. Flower stalks 2 to 4 feet tall are produced in spring from coarse rhizomes. Inflorescences, appearing almost simultaneously with the stalks, are 2 to 8 inches long, but usually about 4 inches. They are profusely branched, the branches ascending at angles of 45° or less. Flowers are numerous, small, and brown. Usually two or more are borne at each branch tip and in the axil of each branch. At maturity, normally in May, seed capsules are spherical. Authors who list both *Juncus biflorus* and *J. marginatus* consider *J. marginatus* a less robust form without rhizomes.

Basal leaves are about ¼ inch wide and up to 12 inches long. Upper leaves are somewhat reduced. Lower leaves usually turn brown before seeds mature.

Young leaves provide some early green forage for cattle, but the plant is not abundant enough to contribute appreciably to the diet.

Range: Texas to Florida, extending north to Massachusetts, southern Michigan, Illinois, Missouri, and Oklahoma.



Perennial. **Stem** 60 – 130 cm tall, forming loose clumps from scaly rhizomes; **leaves** of lower stems 4 – 7 mm wide and 15 – 30 cm long, the upper about half the size of the lower; **inflorescence** a cyme 5 – 20 cm long, branches ascending; **flowers** 1.5 – 3.0 mm in diameter, in clusters of two to several at tips and in axils of inflorescence branches; **sepals** three, acuminate; **petals** three, blunt, scarious-margined; **fruit** a capsule, equaling the perianth.

Common Rush—*Juncus effusus* var. *solutus* Fern. & Wieg.

Common rush, also called rice rush and soft rush, grows in swamps, along stream banks, or on other wet sites. It is represented by several varieties throughout the United States, but only the variety *solutus* occurs in the South.

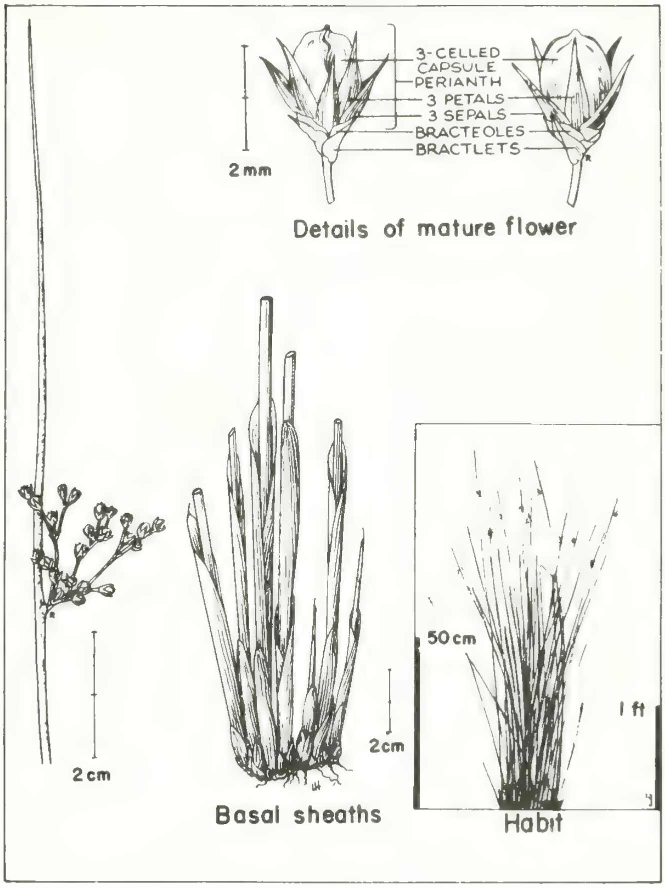
Plant height averages 3 feet, but may reach 6 feet. Numerous round seedstalks arise from a stout rhizome to form dense clumps. The leaf is a brown sheath that encircles the seedstalk to a height of about 5 inches. The blade is reduced to a minute bristle at the sheath tip. Leathery rush, *Juncus coriaceus* MacKenzie, which is also common southwide, has elongate leaf blades terminating some sheaths and a few-flowered, usually branched, inflorescence.

Flower clusters appear to emerge from one side of the flower stalk. Actually, the inflorescence is terminal, subtended by a single, erect bract that may be misidentified as a continuation of the stalk. Common rush is apparently the only southern freshwater rush with this characteristic.

When fully expanded, usually by May 1, the freely branching inflorescence is about 5 inches long. The many small flowers are single, each producing a capsular fruit that yields many tiny seeds.

New leaves and stalks of common rush are nutritious and palatable, but because of its scant foliage, this species provides little forage.

Range: Throughout the United States and Canada.



Perennial. **Stems** to 2 m tall, from stout rhizomes, forming dense clumps; **leaves**, the lower reduced to reddish brown basal sheaths, the upper including a slender scalelike blade 1 mm long; **inflorescence** a terminal cyme 1 – 12 cm in diameter; **flowers** borne singly on cyme branches; **sepals** three, acuminate, about 2 mm long; **petals** three, acuminate, approximately equaling sepals; **fruit** a capsule, equaling or slightly shorter than the perianth.

Needlepod Rush—*Juncus scirpoides* Lam.

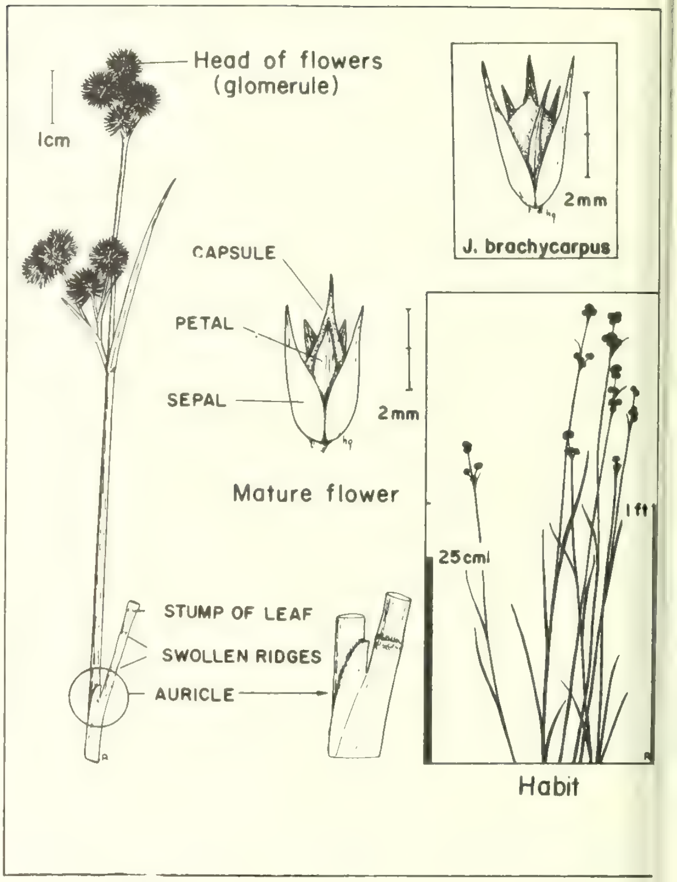
Needlepod rush grows on riverbanks and in shallow ponds, swamps, and wet pinelands. It forms open clumps of slender stalks 1 to 3 feet tall, arising from thick, whitish rhizomes. Two or three leaves are spaced along the stalk, the uppermost subtending the inflorescence. Leaf sheaths, about 1 inch long, are split throughout their length. Blades are round in cross section, with hollow cores divided into chambers by regularly spaced partitions that impart a ribbed appearance to the surface. Leaves are about 4 inches long. They drop early, leaving a short stub.

Inflorescences, when fully expanded, are about 3 inches long and 1 inch wide. Flowers are in heads that may be arranged in either a terminal cluster or in two distinct clusters, one terminal and the other 2 to 3 inches lower on the stem. Heads are each about ¼ inch in diameter and number up to five per cluster. One head per cluster is attached directly to the stem; the others are on short stalks.

Needlepod rush resembles whiteroot rush, *Juncus brachycarpus* Engelm., and the two frequently occur together. The seed capsule of needlepod rush ends in a sharp beak that extends beyond the tips of the flower petals and sepals; the short-beaked capsule of whiteroot rush is exceeded by the floral bracts.

Because of its dearth of foliage, needlepod rush has little forage value.

Range: Texas to Florida, extending north to Oklahoma, Missouri, Illinois, and New York.



Perennial. **Stems** erect, 30 – 80 cm tall, from stout rhizomes; **leaves** terete, 1 – 2 mm in diameter, 5 – 15 cm long, conspicuously septate; **sheaths** open and slightly inflated, with a conspicuous auricle; **inflorescence** a cyme 3 – 15 cm long by 2 cm wide, with 4 to 15 spherical heads, each 5 – 12 mm in diameter, 15- to 40-flowered; **sepals** three, rigid, lance-subulate, about 3 mm long; **petals** three, similar to sepals but slightly shorter; **fruit** a subulate capsule, equaling or usually exceeding the perianth.

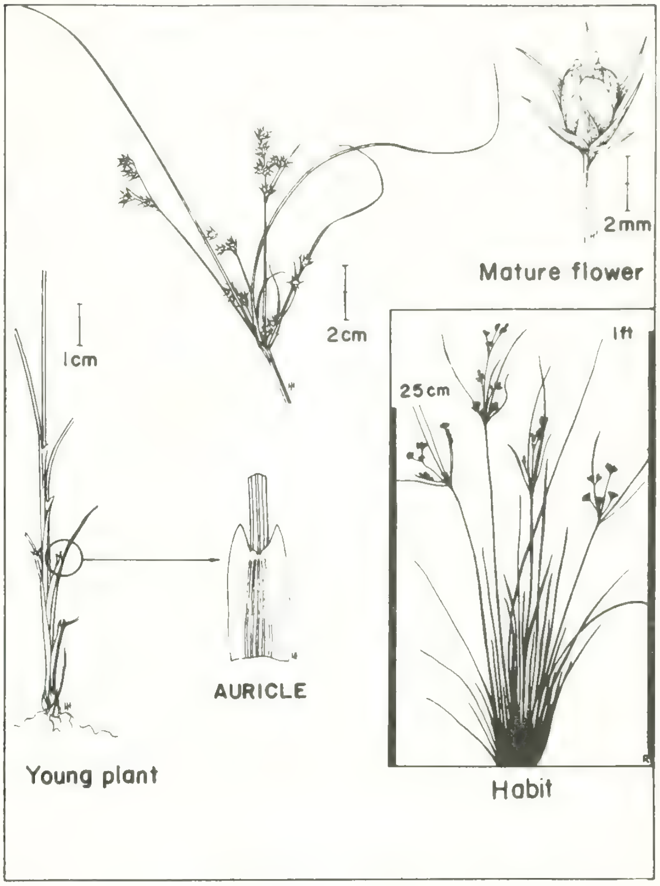
Poverty Rush—*Juncus tenuis* Willd.

Poverty rush, known also as hemp rush and wiregrass rush, grows along trails, in yards, and in other places with heavy traffic. It starts growth in late winter, producing small, dense clumps. Mature stalks reach about 2 feet in height. Leaves are mostly basal, usually less than 1/32 inch wide and about half as tall as the flower stalks. Flowers appear in early spring and seeds mature in April or May. Inflorescences rarely exceed 3 inches in length and 1 inch in width. Flowers, about 1/8 to 3/16 inch in diameter, are borne singly. Leaflike bracts subtend the inflorescence. They are long and narrow, extending above the uppermost flower.

Poverty rush resembles another low-growing rush, *Juncus dichotomus* Ell., which grows mainly on undisturbed sandy sites. Whereas leaves of poverty rush are flattened, those of *J. dichotomus* are almost cylindrical. In poverty rush, a membranous auricle extends beyond the summit of the leaf sheath; the short, rounded auricle of *J. dichotomus* is barely perceptible. Because the leaves of both species are narrow, magnification helps in detecting these differences.

Poverty rush is seldom grazed except in winter when better herbage is unavailable. It supplies little forage on most sites.

Range: Throughout most of North America.



Perennial. **Stems** in clumps, 10 – 60 cm tall; **leaves** basal, about one-half the height of stems, 0.5 – 1.0 mm wide; **sheath** with scarious margin; **auricle** scarious, 1 – 3 mm long; **inflorescence** a cyme 1.5 – 15.0 cm long, subtended by involucral bracts that often exceed the cyme; **flowers** 3 – 5 mm in diameter, borne singly at tips and in axils of ascending branches of cymes; **sepals** and **petals** lance-subulate, scarious-margined, equal in size; **fruit** a capsule, usually exceeded by the perianth.

Roundhead Rush—*Juncus validus* Coville

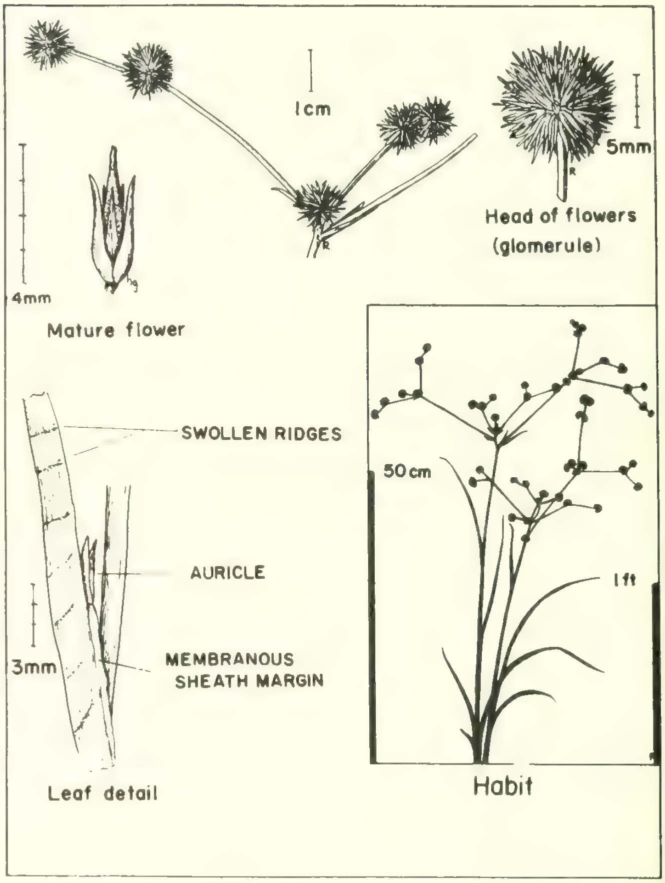
Roundhead rush grows mainly in swales, drainages, and sandy flatwoods. It forms loose, leafy clumps of stems 2 to 3 feet tall. Although it is not generally abundant, its large, stiff inflorescence is conspicuous.

Flower stalks emerge in midspring and seeds mature by early summer. The inflorescence branches as it grows, often spreading to a foot or more at maturity. Spherical flower heads, about ½ inch in diameter, are scattered throughout the inflorescence.

Leaves are mostly basal, the largest about 12 inches long and ¼ inch wide. They are slightly flattened, hollow, and segmented by internal partitions that impart a knotty feel to the surface. This "knotleaf" characteristic is common to several species, however, including needlepod rush. The flattened leaves of roundhead rush superficially resemble those of blue-eyed-grass, *Sisyrinchium* spp., but the knotty blades are useful in distinguishing the species before flower stalks appear. The larger but closely related flatleaf rush, *Juncus polycephalus* Michx., has strongly flattened leaves and its capsules are capped by a solid beak, not split at the tip as in roundhead rush.

Cattle graze roundhead rush in late winter and early spring, but rushes generally provide little forage.

Range: Texas to Mississippi and Missouri.



Perennial. **Stems** erect, 30 – 80 cm tall, from short, knotty rhizomes; **leaves** 2 – 7 mm wide, up to 40 cm long, conspicuously septate; **sheaths** scarious-margined, terminated by lanceolate auricles 2 – 4 cm long; **inflorescence** an open, widely branching cyme up to 50 cm wide, with spherical, many-flowered heads at branch tips and in axils; **heads** 1.0 – 1.5 cm in diameter; **flowers** with sepals and petals equal, lance-subulate, 4 – 6 mm long; **fruit** a lance-subulate capsule, exceeding the perianth.

FORBS

The term "forb" as used in this handbook and in range management generally, refers to herbaceous plants other than grasses (family Gramineae) and grasslike plants (families Cyperaceae and Juncaceae). Some use the term "weed" for such plants, but the word has a noxious connotation; a forb (or grass or grasslike plant) becomes a weed where its presence is not welcome, as in a lawn, garden, flower bed, or soybean field.

Forbs are numerous on southern pine ranges, occasionally comprising up to 20 percent of the ground cover. They may add variety to the forage supply, provide food and cover for wildlife, and improve the soil. Some are more tolerant of shade or plant competition than others. On the average, forbs furnish about 4 percent of the cattle diet. Because many species surpass grasses in protein, phosphorus, and calcium content, the quantity consumed is not a reliable indication of their contribution to cattle nutrition.

Several forbs are toxic, but cattle poisoning is infrequent. These toxic plants are usually unpalatable; moreover, they seldom are abundant enough to cause trouble. With rare exceptions, cattle consume poisonous species in lethal quantities only on overgrazed ranges.

Although forbs representing dozens of plant families are found in the South, the most common species on longleaf pine-bluestem range are legumes (Leguminosae) and composites (Compositae).

Legumes

The legume family (Leguminosae) is economically one of the world's most important plant families. It includes peas, beans, peanuts, and many valuable pasture plants—especially the clovers *(Trifolium* spp., *Medicago* spp., *Melilotus* spp.). Legumes vary widely in life form, from annual forbs to trees over 100 feet tall. Although they are generally characterized by compound leaves, irregular pealike flowers, and seed pods that split longitudinally when ripe, these features are far from universal. Some legumes have simple leaves, several have symmetrical flowers, and pods of some species remain closed at maturity.

Native legumes are numerous on southern pine ranges but usually comprise a small part of the total forage. Legume herbage is rich in protein; thus, small quantities may appreciably improve the diet. Most herbaceous legumes are palatable to cattle, but a few species—Nuttall wildindigo, for example—are grazed sparingly, if ever.

Seeds of many legumes are favorite foods of wildlife. Several species are grown in cultivated food patches to improve quail habitat.

Nuttall Wildindigo—*Baptisia nuttalliana* Small

Nuttall wildindigo is a bushy, herbaceous perennial growing from large woody rootstocks. It is most common in south-central Louisiana and southeastern Texas. Mature plants are usually 2 to 3 feet tall. On dry sites that are heavily grazed and frequently burned, Nuttall wildindigo is often an abundant understory plant. It seldom occurs on open cutover sites, probably because of grass competition.

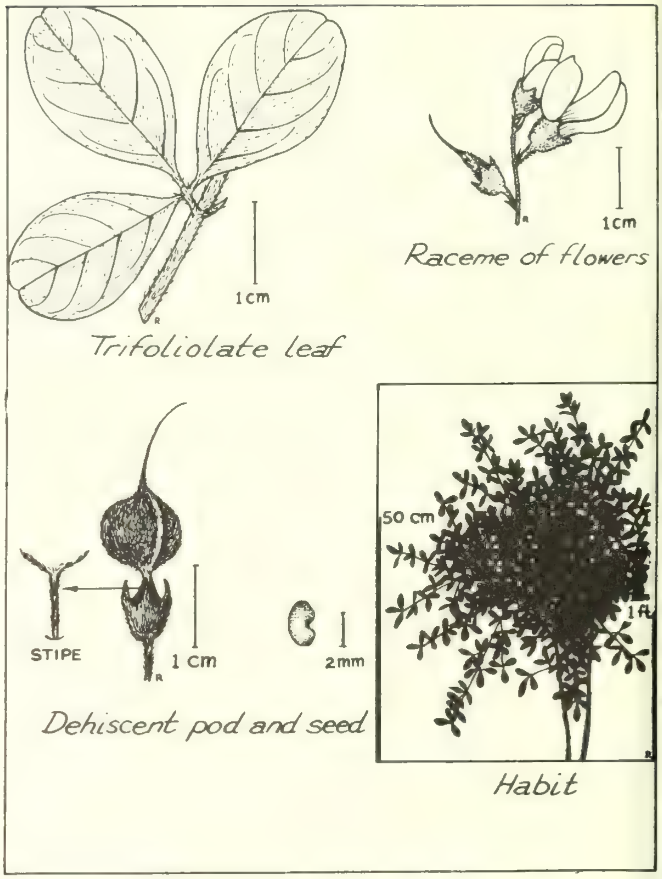
New growth emerges in late winter while most other forbs are dormant. Plants bloom in the spring and mature in early summer, turning blue black (indigo) at maturity. Pale yellow flowers are in terminal racemes or solitary in leaf axils; commonly, these arrangements are mixed. Leaves are palmately compound with three oblanceolate or elliptical leaflets 1 to 3 inches long.

Several other wildindigos, also called false-indigos, occur throughout the South but most have limited distribution. Others with ranges extending west of the Mississippi River and which apparently intergrade with *Baptisia nuttalliana* and each other are: whitestem wildindigo, *B. bracteata* var. *laevicaulis* (Gray ex Canby) Isely—a low-growing plant with drooping terminal racemes of yellow flowers; round wildindigo, *B. sphaerocarpa* Nutt.-an upright branching plant with several to many erect terminal racemes of yellow flowers; and Atlantic wildindigo, *B. lactea* (Raf.) Thieret—(*B. leucantha* T. & G.) an upright branching plant with an elongated terminal raceme of white flowers.

Species whose ranges are east of the Mississippi River include pineland wildindigo, *B. lanceolata* (Walt.) Ell., with leaflets 2 to 4 inches long and single yellow flowers in the upper leaf axils, and yellow wildindigo, *B. tinctoria* (L.) R. Br., a small-leaved, erect, often bushy plant with yellow flowers terminating the tallest branches. *B. tinctoria* has been used for medicinal purposes in the Appalachian region as a tonic or purgative.

Only one species, Atlantic wildindigo, is reported as poisonous to livestock, but any species should be suspect if abundant. The seeds of *Baptisia* have limited value for wildlife food.

Range: East Texas, Louisiana, Arkansas, and western Mississippi.



Perennial. **Stems** 40 – 100 cm tall, much branched from thick rhizomes; **leaves** trifoliolate, stipulate; **leaflets** 2 – 6 cm long, cuneate to obovate-cuneate, rounded or notched at the apex, glossy above, dull beneath, with scattered pubescence; **flowers** papilionaceous, solitary in upper leaf axils or 1 to 12 in racemes at the tips of leafy branches; **calyx** 8 – 10 mm long, campanulate, silky pubescent; **corolla** pale yellow; **keel** about 15 mm long; **standard** with reniform blade 1.2 – 1.8 cm broad; **legume** pubescent, subglobose, long-stipitate, thickwalled and woody with a long, slender beak (style), the body 1.0 – 1.7 cm long seeds many, about 2.5 mm long, bean shaped, yellow brown, smooth.

Showy Partridgepea—*Cassia fasciculata* Michx.

Showy partridgepea is an annual that grows on a variety of sites throughout the eastern United States. It is common on disturbed areas, often forming extensive colonies along firelines, roadside ditches, and in old fields.

Height is usually about 2 feet, but ranges from 6 inches to 3 feet. In years of normal rainfall, the bright yellow flowers appear continuously through most of the growing season. The leaves are pinnately compound, usually with 10 to 15 pairs of leaflets. A small, dark, saucer-shaped nectary, or honey gland, is located on the leaf petiole slightly below the lowest pair of leaflets. Seed pods are less than 3 inches long.

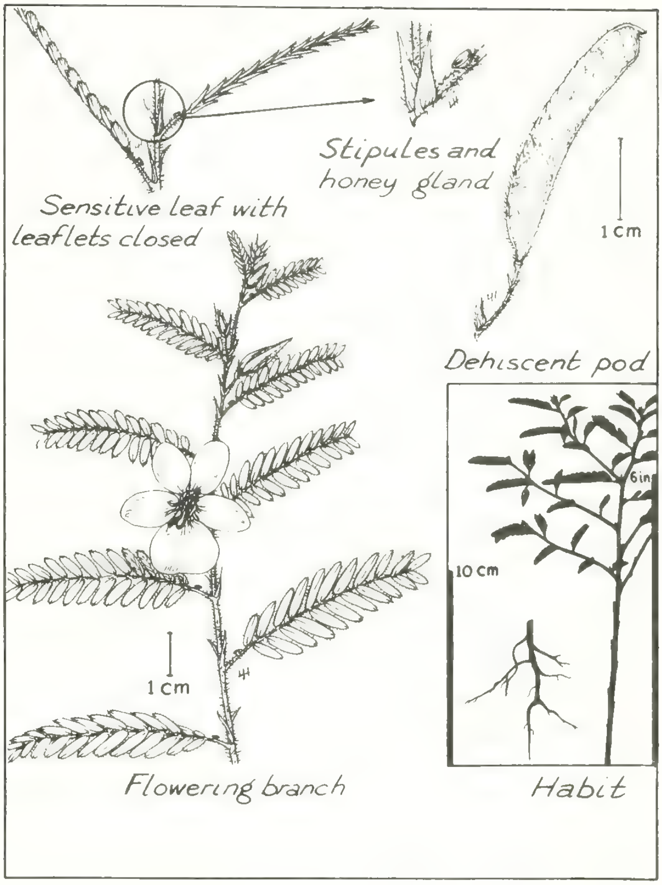
Plants differ widely in several characters, particularly size and pubescence, and several varieties have been named. *Cassia fasciculata* var. *brachiata* (Pollard) Pullen ex Isely, grows on wet sandy flats and other moist pinelands of south Alabama and Florida. Largest plants reach 8 feet in height, leaves have up to 25 pairs of leaflets, and the pod may be 4 inches long.

Sensitive partridgepea, *C. nictitans* L., a smooth small-flowered species, is common throughout the Gulf Coastal Plain. It resembles showy partridgepea, but the flowers are much smaller and have 5 stamens compared to 10 in showy partridgepea. *Cassia aspera* Muhl. is a small-flowered partridgepea common on sandy pine sites of the Atlantic Coastal Plain from Florida to South Carolina.

Cassia deeringiana (Small and Pennell) J.F. Macbr., a perennial partridgepea with long horizontal rootstocks, is found on sandy scrub oak sites in Florida, southern Alabama, and southwestern Georgia. The perennial plant is similar to, and may be mistaken for, showy partridgepea. *C. deeringiana* is essentially hairless, and the annual *C. fasciculata* is usually noticeably hairy; the rootstock on *C. deeringiana*, however, is the most reliable distinguishing character.

Although showy partridgepea foliage is highly nutritious, it is listed as a poisonous plant and should be considered potentially dangerous to cattle (Kingsbury 1964). The seeds are readily eaten by quail and patches are widely cultivated in the South to augment natural food supplies. Periodic burning favors all partridgepeas.

Range: Texas to Florida, extending north to South Dakota, southern Ontario and Massachusetts.



Annual. **Stems** 15 – 100 cm tall, from a taproot, glabrous to densely puberulent to villous; **leaves** even-pinnate, sensitive, with nectaries near the middle of the petiole; **leaflets** 12 to 36, linear-oblong, 1.0 – 2.5 cm long, 2 – 6 mm wide, inequilateral; **stipules** persistent, striate; **inflorescence** a 1- to 6-flowered axillary fascicle; **pedicels** 1 – 2 cm long; **sepals** lanceolate, 9 – 12 mm long, acute; **petals** bright yellow, almost equal, 1 – 2 cm long; **stamens** 10, unequal, 10 – 13 mm long; **legume** elastically dehiscent, 3 – 7 cm long, 5 – 7 cm broad, glabrate or appressed-puberulent to villous.

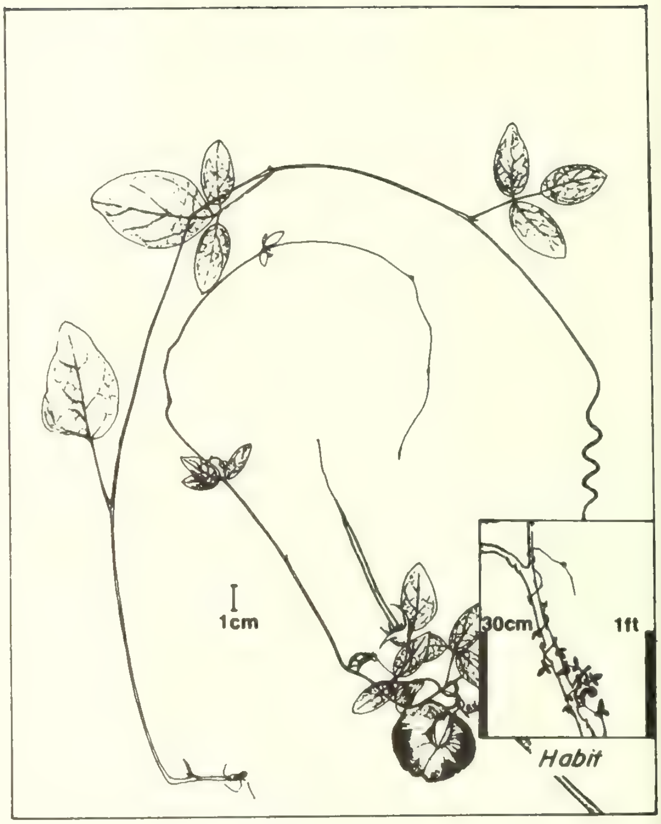
Butterflypea—*Centrosema virginianum* (L.) Benth.

This showy, twining, herbaceous legume is common on well-drained sites throughout the southern states. The flowers are flattened, almost circular, pink, and about 1 inch wide. The slender pods, averaging about 4 inches long, are produced throughout the summer. Leaves are pinnately compound with three, usually ovate, leaflets up to 3 inches long. Upper surfaces of leaflets are reticulately divided by veins paler in color than areas between the veins.

Butterflypea is closely related to Atlantic pigeonwings, which is also called butterflypea in some plant books. Flowers of both differ from the typical legume flower by having the larger petal (standard) beneath the other flower parts. The two can be separated by calyx (sepal) characteristics; the calyx tube of *Centrosema virginianum* is shorter than the lobes, while that of *Clitoria mariana* is longer than the lobes. The twining habit of butterflypea can also be used to distinguish the two. While foliage of both may appear hairless, butterflypea usually has fine short white hairs on stems, petioles, and upper leaf surfaces.

Because of its limited abundance, butterflypea has essentially no value as forage for livestock and deer. The seeds are eaten readily by bobwhite quail and other birds and small mammals.

Range: Texas and Arkansas, extending east to Florida, then north to Tennessee and New Jersey.



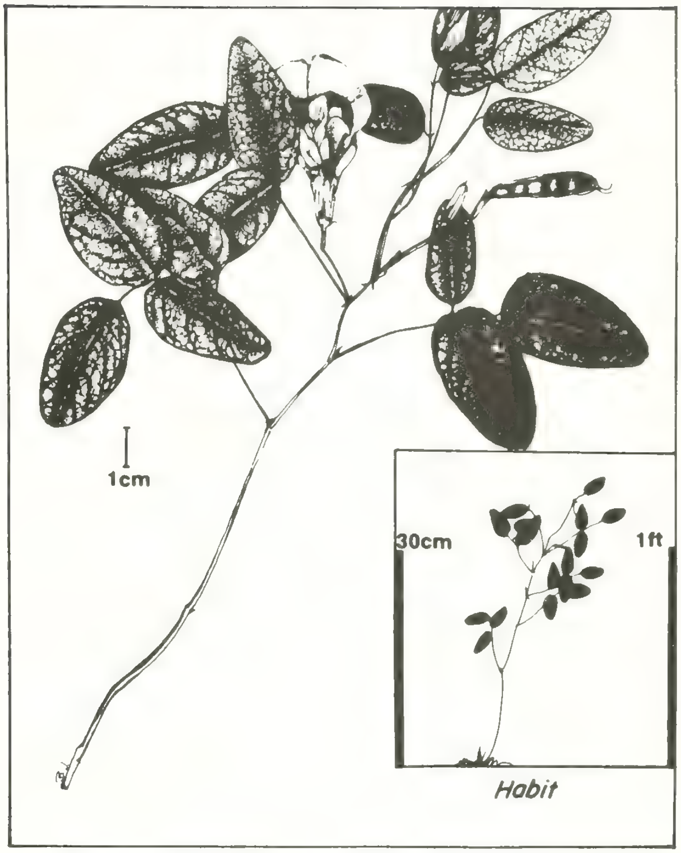
Perennial. **Stems** herbaceous, trailing or twining, to 1.5 m long, minutely pubescent throughout; **leaves** trifoliolate, leaflets ovate to oblong or elliptic, reticulate, 2 – 7 cm long and 0.5 – 3.0 cm wide, stipellate; **stipules** ovate-lanceolate to lanceolate, striate, 1.5 – 4.0 mm long, persistent; **inflorescences** axilliary; on peduncles 2 – 4 cm long, flowers one to three, pedicellate, pedicels and flowers subtended by stipule-like bracts; **calyx** tube broadly hemispheric, 4 – 5 mm long, lobes linear-subulate, 0.6 – 1.4 cm long; **corolla** pale blue violet to lavender, the standard 2 – 4 cm long, spurred near base; **legume** linear, flattened, 7 – 14 cm long, 0.3 – 4.0 mm broad, 10- to 20-seeded, with a persistent, beak-like style; **seeds** black, 2 – 3 mm long.

Atlantic Pigeonwings—*Clitoria mariana* L.

Closely related and similar to butterflypea, Atlantic pigeonwings occurs on dry sites throughout the South, often in association with butterflypea and various tickclovers *(Desmodium* spp.). Early vegetative growth of *Clitoria, Centrosema,* and several of the larger, ovate-leaved tickclovers require careful scrutiny. All have stipels; *Clitoria* and *Centrosema* also have conspicuous stipules. Growth form as expressed in later growth is useful for separation: *Clitoria* is erect or trailing, *Centrosema* is twining, and *Desmodium* is usually erect. Both *Clitoria* and *Centrosema* have showy flowers ranging from blue to purplish or sometimes almost white.

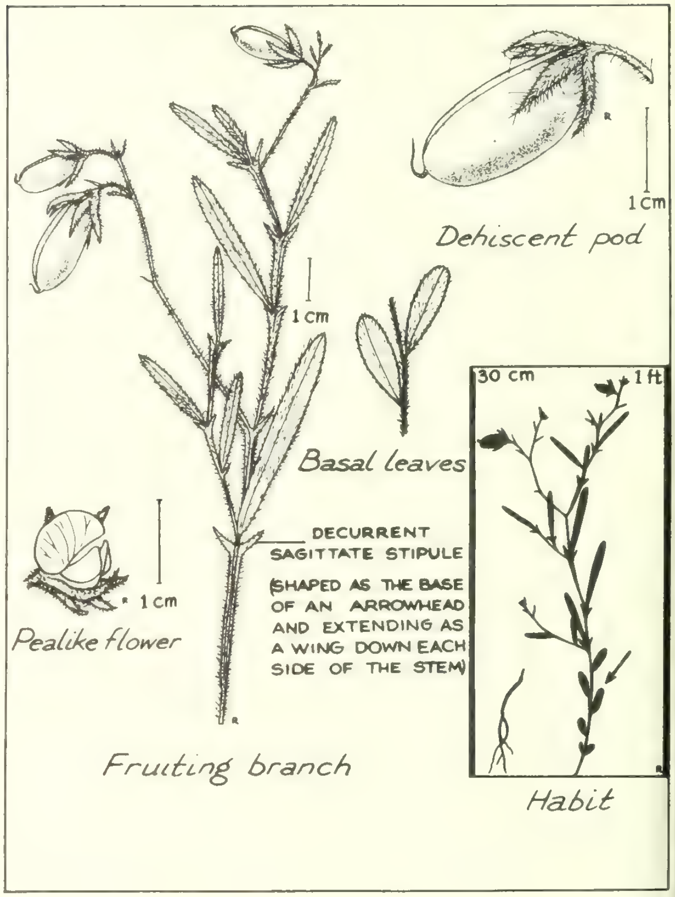
Although Atlantic pigeonwings is not generally abundant enough to be considered a valuable forage or wildlife food source, quail, turkeys, doves, and other birds use the seed for food.

Range: Arizona to Florida, extending north to New York, West Virginia, Ohio, Indiana, Illinois, and Iowa.



Perennial. **Stems** erect or trailing, glabrous to short-pubescent; **leaves** pinnately 3-foliolate; **leaflets** entire, ovate, lanceolate, ovate-oblong, or elliptic, 2 – 7 cm long, glabrous above and glabrous or occasionally short-pubescent beneath, stipellate; **stipules** ovate-lanceolate to lanceolate, 2 – 4 mm long, tardily deciduous, striate; **racemes** axillary, peduncles 0.5 – 4.0 cm long, 1- to 3-flowered; **pedicels** glabrous or rarely short-pubescent, 4 – 10 mm long, each subtended by a triangular to lanceolate, striate bract 1 – 3 mm long and with a pair of linear bractlets 3 – 6 mm long at or near the summits; **calyx** usually glabrous or rarely short-pubescent, somewhat bilabiate, tube cylindric, 1 – 2 cm long, upper lobes widely triangular, acute, 4 – 6 mm long, lateral lobes ovate-lanceolate, acuminate, 5 – 7 mm long, lowermost lobe lanceolate, acuminate, 6 – 8 mm long; **petals** pale blue or lavender, the standard spurless, 4 – 6 cm long, 3 – 4 cm wide; **stamens** monadelphous; **legume** flattened, oblong-linear, 3 – 6 cm long; **stipe** elongate, 1 – 2 cm long; **seeds** sticky.

Arrow Crotalaria—*Crotalaria sagittalis* L.


1 cm
Dehiscent pod
1 cm
Basal leaves
30 cm
1 ft
DECURRENT SAGITTATE STIPULE
(SHAPED AS THE BASE OF AN ARROWHEAD AND EXTENDING AS A WING DOWN EACH SIDE OF THE STEM)
1 cm
Pealike flower
Fruiting branch
Habit

Arrow crotalaria is an annual or a short-lived perennial seldom more than 15 inches tall. It is most common on dry sandy or gravelly soils, especially on disturbed sites. The lower leaves are elliptical and about 1 inch long, whereas upper leaves are lanceolate and up to 3 inches long. Arrowhead-shaped stipules give stems a winged appearance. Flowers, which usually appear from June through September, are small and yellow, resembling those of garden peas. The inflated pods are about 1 inch long and half as broad.

Several other crotalarias resemble arrow crotalaria in flower and pod characteristics, but only *Crotalaria purshii* DC. has the same long narrow leaves. The principal difference between the two is that stems and sepals of arrow crotalaria have conspicuous spreading hairs, while those of *C. purshii* have obscure hairs pressed flat against the stem or sepal. Some taxonomists consider *C. purshii* a regional variety of arrow crotalaria. The crotalarias are often called rattleboxes, since the loose seeds rattle in the mature pod. Showy crotalaria, *C. spectabilis* Roth, and slenderleaf crotalaria, *C. brevidens* Benth. (formerly *C. intermedia* Kotschy), are two robust annual weeds on agricultural lands. Showy crotalaria has wide simple leaves and slenderleaf has trifoliolate leaves with narrow leaflets.

Arrow crotalaria is poisonous to livestock. Because plants are usually scarce, however, they rarely constitute a threat to cattle.

Range: Texas to Florida, extending north to South Dakota and Massachusetts.

Annual or weak perennial. **Stems** 10 – 40 cm tall, simple to bushy branched, loosely villous to hirsute; **basal leaves** simple, small, oval; **upper leaves** linear-oblong to lanceolate, the larger 3 – 7 cm long, 8 – 15 mm wide; **stipules** inversely sagittate, decurrent; **flowers** papilionaceous, two to four on terminal or axillary peduncles 1 – 4 cm long; **calyx** 10 – 12 mm long, 5-cleft, loosely villous or hirsute; **corolla** 8 – 10 mm long, yellow; **legume** 1.5 – 3.0 cm long, about 1 cm thick, strongly inflated, dull brown; **seeds** 2.3 – 3.0 mm broad, obliquely reniform.

Tickclovers—*Desmodium* spp.

The tickclovers, also called beggarlice, sticktights, or ticktrefoils, are so named because the flat, minutely bristled fruits stick to clothing and animal hair. About 15 species, all perennials, occur throughout the South. Leaflet length of southern tickclovers varies from less than ½ inch to 6 inches, and leaflet shape varies from narrowly linear to ovate or round. Flowers are similar among most species and fruits are necessary for identification. Flowers are pealike, less than ½ inch long, and pink to purple (some white). The fruit is a flat jointed pod that may remain intact at maturity or break apart to become the familiar "ticks" or "beggarlice."

Desmodium may be confused with *Lespedeza* in the vegetative state, but the two are readily distinguishable when in the flower or fruit stages. Tickclovers have a pair of stipels at the base of the terminal leaflet and a single stipel at the base of each lateral leaflet. Stipels are lacking in lespedezas.

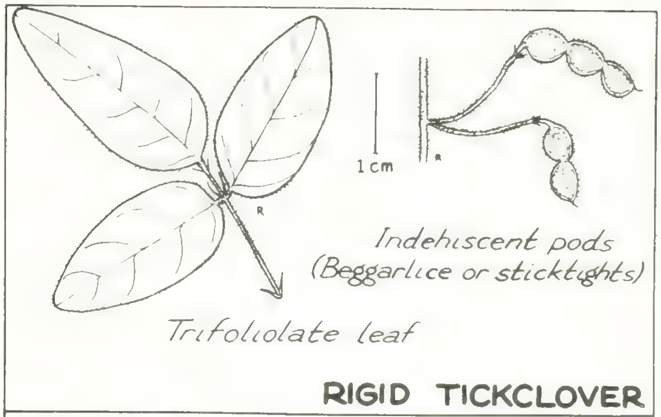
Although tickclovers are nutritious and palatable, the plants are seldom abundant enough to yield much livestock forage, although most are high-use deer food plants. Seeds are valuable quail food.

Littleleaf tickclover, *Desmodium ciliare* (Muhl. ex Willd.) DC., probably the most common and thus most important tickclover in the South, is illustrated as an example and described below.

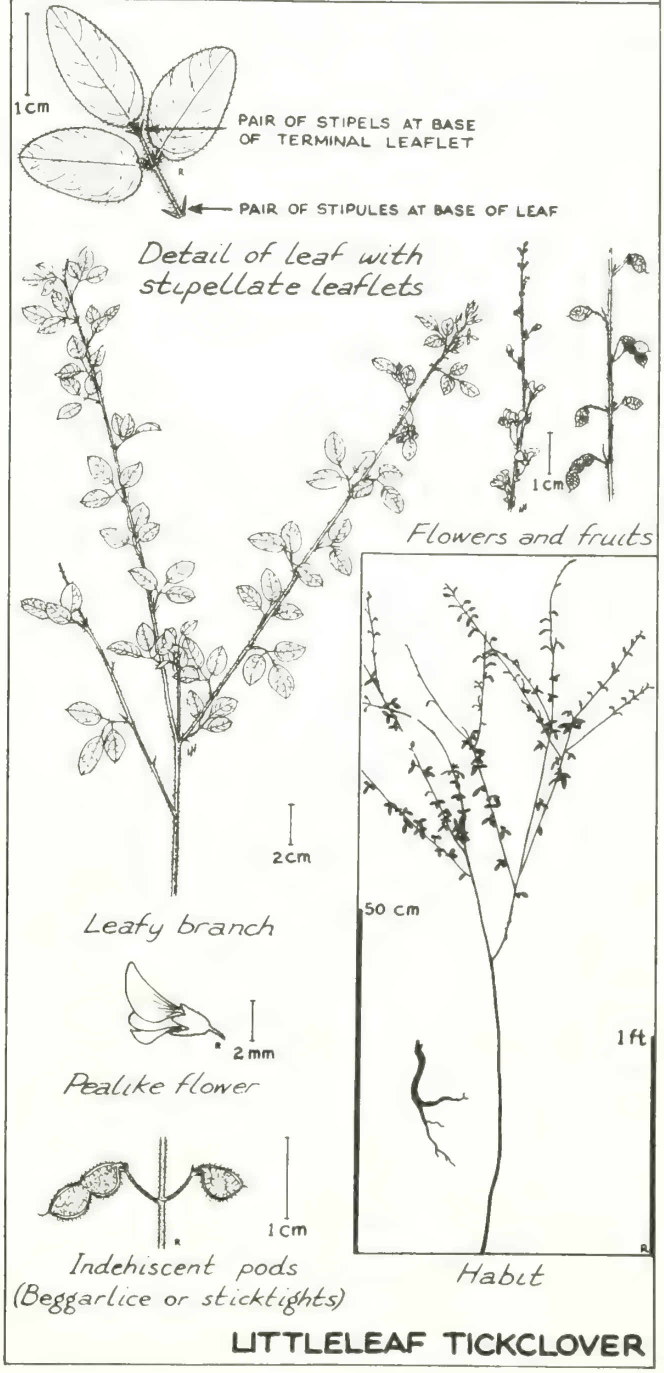
The similar rigid tickclover, *D. rigidum* (Ell.) DC., also grows southwide. It can be distinguished by its leaflets, which are long-ovate instead of blunt-tipped, and unequal in size, the terminal longer than the laterals. Roundleaf tickclover, *D. rotundifolium* DC., and sand tickclover, *D. lineatum* DC., are prostrate, trailing species common on dry pinelands throughout the South. Other species common southwide are smooth tickclover, *D. laevigatum* (Nutt.) DC., Maryland tickclover, *D. marilandicum* (L.) DC., panicled tickclover, *D. paniculatum* (L.) DC., and velvetleaf tickclover, *D. viridifolium* (L.) DC.

Range (Littleleaf tickclover): Texas and Nebraska to Florida and Michigan.

Perennial. **Stems** 40 – 100 cm tall, slender, usually spreading-pilose; **leaves** trifoliolate; **stipules** linear-subulate, 2 – 4 mm long, quickly deciduous; **leaflets** ovate to orbicular, pilose, terminal leaflet 1 – 3 cm long; **stipels** apiculate; **flowers** papilionaceous, small, rose purple, in large terminal racemes; **fruit** a loment with one to three articles, 4.0 – 5.5 mm long, 2.7 – 4.0 mm wide, covered with short, stout hooks.



RIGID TICKCLOVER


1cm
PAIR OF STIPELS AT BASE OF TERMINAL LEAFLET
PAIR OF STIPULES AT BASE OF LEAF
Detail of leaf with stipellate leaflets
1cm
Flowers and fruits
2cm
Leafy branch
50 cm
1 ft
Habit
2 mm
Pealike flower
1 cm
Indehiscent pods
(Beggarlice or sticktights)

LITTLELEAF TICKCLOVER

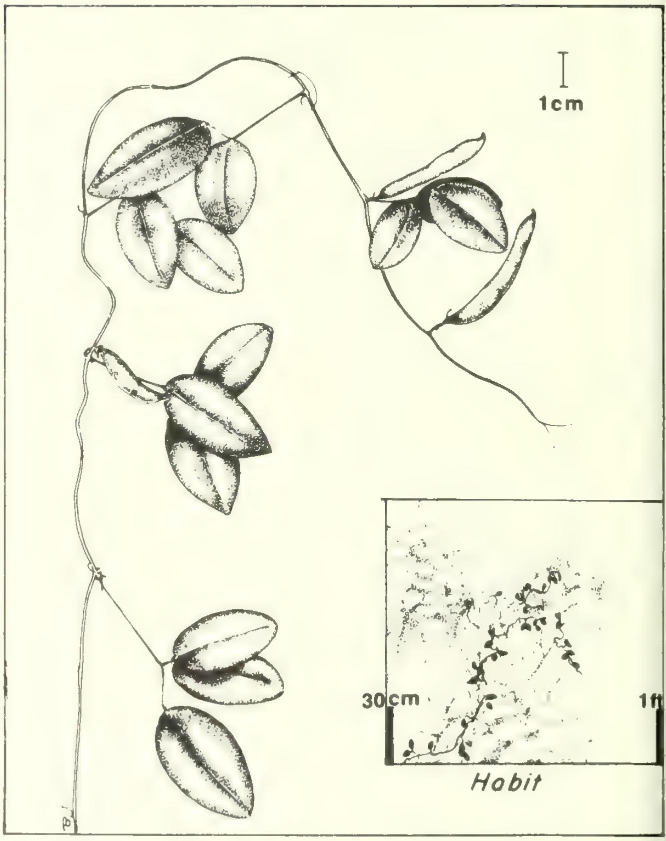
Downy Milkpea—*Galactia volubilis* (L.) Britt.

The milkpeas, like the tickclovers, are a group of legumes whose seeds are recognized as choice food for the bobwhite quail. Downy milkpea is fairly common southwide. Shapely milkpea, *Galactia regularis* (L.) BSP., a trailing plant, and erect milkpea, *G. erecta* (Walt.) Vail, the only species that is not trailing or twining, are also found on sandy sites throughout the South. Leaves of most species are pinnately compound with three leaflets, although *G. elliottii* Nutt., a species of the Atlantic Coastal Plain, has five to nine leaflets.

Downy milkpea is a twining or climbing herbaceous vine with sparsely to densely pubescent stems. Leaflets are ovate, ½ inch to 1½ inches long. Flowers are pealike, pink to rose, less than ½ inch long. The fruit is a flattened seed pod, up to 2 inches long and ¼ inch wide, covered with short white hairs.

The species is variable throughout its range, and the separation of *G. volubilis* and *G. regularis* is difficult in some areas, leading some botanists to suspect that the two belong together in one widespread, variable species. *Galactia macreei* M. A. Curtis, a southwide milkpea, is similar and possibly not distinct from downy milkpea. While the latter usually has spreading hairs on the stems and fruit, *G. macreei* has appressed, short pubescence.

Range: Eastern Texas and southern Kansas to Florida and Long Island.



Perennial. **Stems** twining or climbing, sparsely to densely spreading-pubescent; **leaves** pinnately trifoliolate rachis 2 – 18 mm long; **leaflets** oblong, oblong-ovate or elliptic, 2 – 4 cm long, glabrous or nearly so above, and glabrate to spreading pilose beneath; **racemes** with peduncles and rachises sparsely to densely spreading short-pubescent, 3 – 15 cm long; **calyx** tube 2.0 – 2.5 mm long, lobes 2.0 – 3.5 mm long; **petals** pink to roseate, the standard 7 – 10 mm long; **legume** 2.0 – 5.5 cm long, 4 – 5 mm broad, spreading short-pubescent; **seed** mottled, 2 – 3 mm long.

Common Lespedeza—*Lespedeza striata* (Thunb.) H. & A.

Common lespedeza, or Japanese clover, is an annual forage legume native to Asia. Following its introduction into Georgia more than 100 years ago, it escaped cultivation and spread rapidly across the South. Now it is common on dry, open, closely grazed range and rarely found under timber stands. Several other Asian lespedezas have been introduced into the United States, particularly in the South, for forage, erosion control, and wildlife food plantings. Shrubby species like bicolor lespedeza, *Lespedeza bicolor* Turcz., are widely planted for bobwhite quail food.

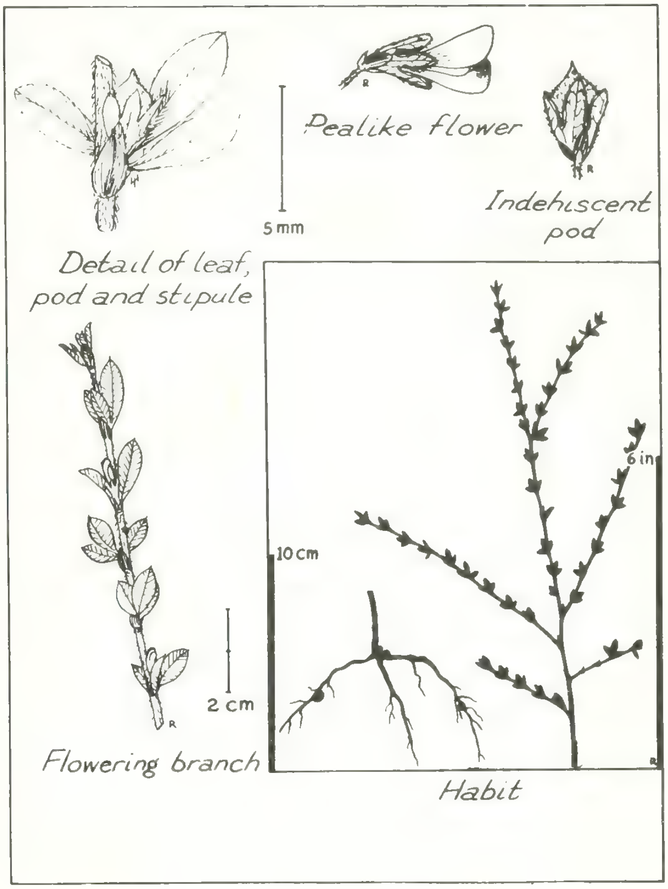
Plants of common lespedeza are usually less than 1 foot tall. Stems are many-branched and decumbent, or they may be prostrate if grazed closely. Leaves are trifoliolate, the obovate to nearly elliptical leaflets ⅓ to 1 inch long. Leaflet veins are conspicuous, with straight, parallel laterals extending outward at about 45° from the midrib. Flowers are of two kinds, with and without corolla, and are borne singly or in clusters of two to four in upper leaf axils. Corollas of complete flowers are pinkish and about ¼ inch long.

Several native lespedezas also grow on sandy pine sites. Among the most common are hairy lespedeza, *L. hirta* (L.) Hornem., and slender lespedeza, *L. virginica* (L.) Britt. Hairy lespedeza is distinguishable by its height, which reaches 4 feet, and its large leaflets —up to 2 inches long and an inch wide. Slender lespedeza is a slender, usually unbranched plant with small, narrow, crowded leaves. A prostrate species, creeping lespedeza, *L. repens* (L.) Bart., is common on sandy sites throughout the South. All native species are perennial but collectively make up only a small percentage of the forage available.

Lespedezas may be confused with tickclovers. Both have trifoliolate leaves subtended by stipules nd their flowers are similar. They can be distinguished readily by their seed pods. Lespedeza pods re short, oval, usually one-seeded, and intact at maturity, while those of tickclover are elongate and reak into two or more one-seeded segments at matu- ty. Lespedezas also lack the stipels that subtend ckclover leaflets. Separation by vegetative charac- eristics is described under the discussion of *Desmo- ium*.

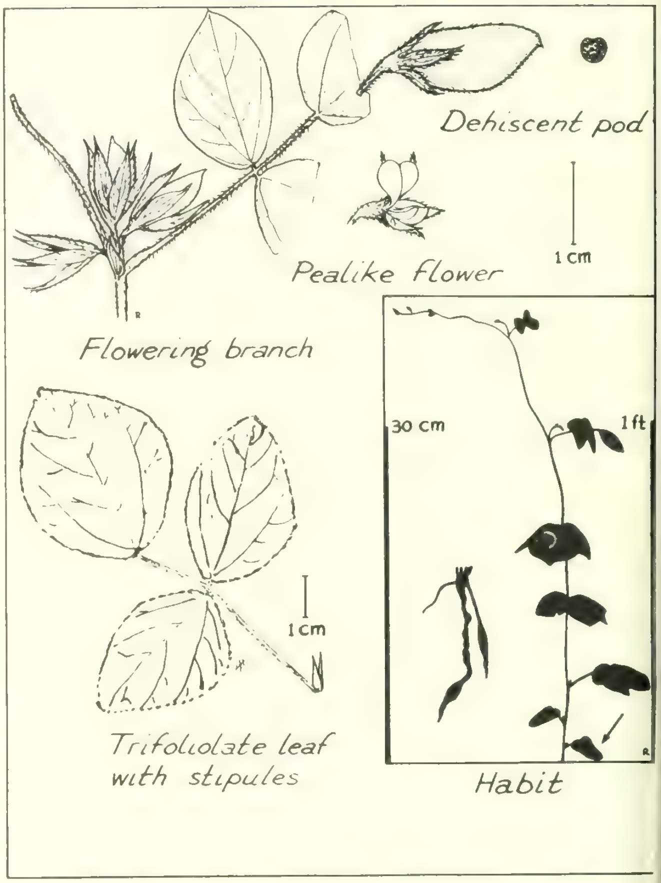
Like most pasture legumes, common lespedeza is utritious and palatable but seldom abundant in nge vegetation. It is often an important constituent seeded firebreaks on forest ranges. The ability to roduce seeds under close grazing makes common spedeza a reliable source of food for quail, which eat oth seeds and spring leaves.

Range: Texas and Florida, extending north to ansas and Pennsylvania.



Annual. **Stems** decumbent, 10 – 40 cm tall, diffusely branched, retrorsely pubescent; **leaves** pinnately trifoliolate; **stipules** 4 – 6 mm long; **leaflets** short-petioled, oblong-obovate, 1 – 2 cm long, striate; **flowers** of two kinds, apetalous ones mixed with complete pinkish ones in axils, one to four on short peduncles; **legume** a flat, 1-seeded pod barely exceeding the persistent calyx.

Hairy Rhynchosia—*Rhynchosia difformis* (Ell.) DC.



Hairy rhynchosia, or hairy snoutbean, is a trailing or twining perennial herbaceous vine with ovate leaflets. Most leaves are trifoliolate with terminal leaflets about 1½ inches long and almost round. Lateral leaflets are smaller, and length exceeds width. Basal leaves often develop only a single leaflet. Although differences among leaves are alluded to in its specific name *difformis,* meaning "two forms," several rhynchosias have this character.

Stems arise from tuberous rootstocks and may reach 3 feet. They are erect when young but become trailing or twining as they elongate. Inconspicuous yellow flowers about ½ inch long are in short-stemmed axillary clusters.

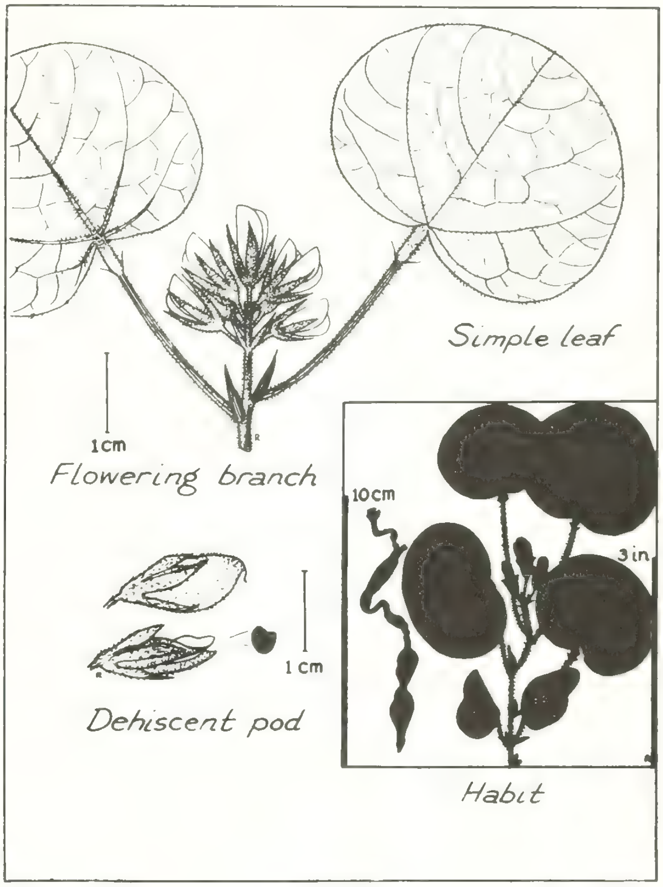
Species that may associate and intergrade with hairy rhynchosia include broadleaf rhynchosia, *Rhynchosia latifolia* Nutt. ex Torr. & Gray—found only west of the Mississippi River—and erect rhynchosia, *R. tomentosa* (L.) H. & A. Whereas the axillary racemes of hairy rhynchosia are about 2 inches long, those of broadleaf rhynchosia may be up to 12 inches. Erect rhynchosia, which grows southwide, is upright and has only trifoliolate leaves, with softly pubescent, ovate to elliptic leaflets. Least rhynchosia, *R. minima* (L.) DC., a trailing, twining plant with small flowers and usually small leaflets, is common on silty-clay alluvial soils of the lower Coastal Plain from Texas to Georgia.

Although hairy rhynchosia is abundant, the plants are too scattered to produce much forage. Quail, doves, and other birds eat the seeds.

Range: Texas to Florida, extending north to Missouri and Virginia.

Perennial. **Stems** from long tuberous roots, erect at first, then trailing and twining, to 1 m long, densely retrorse-hirsute on the angles, lightly pubescent between; **leaves** of two kinds, the basal ones simple, reniform, those above trifoliolate; **leaflets** elliptic to broadly ovate, 2 – 5 cm long, the terminal larger, sparingly pubescent on both sides; **flowers** in short, dense, axillary racemes, 2 – 4 cm long; **corollas** yellow, 5 – 11 mm long; **legume** 1.5 – 2.0 cm long, 8 mm wide; **seeds** lenticular, 2.5 – 3.0 mm in diameter, dark brown.

Dollarleaf Rhynchosia—*Rhynchosia reniformis* DC.



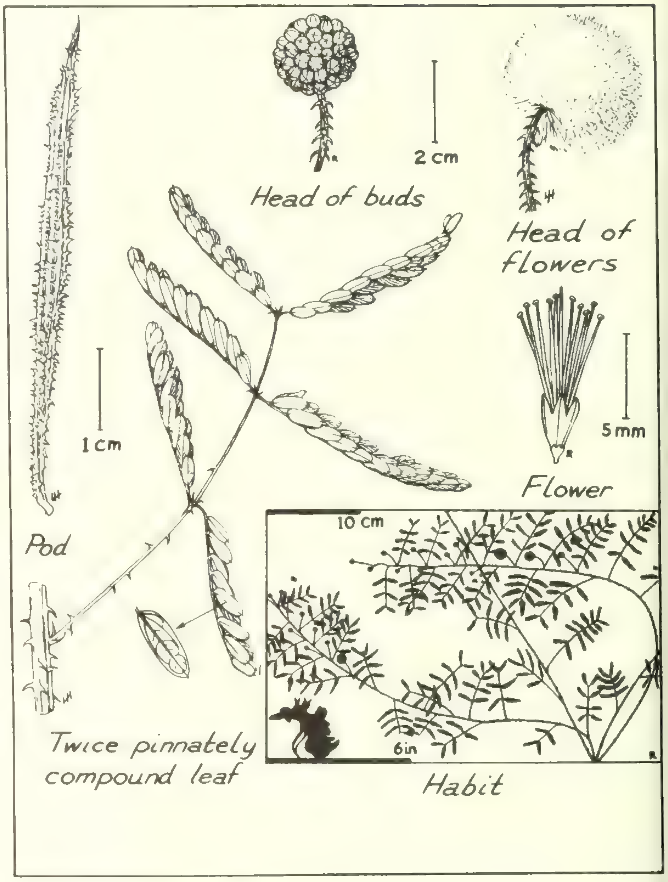
Dollarleaf rhynchosia is a small, erect perennial found throughout the Gulf Coastal Plain. It is most abundant on sandy sites. Stems are 3 to 9 inches tall, growing from slender, woody rhizomes. Leaves are simple or rarely trifoliolate, round to kidney shaped, and average 2 inches in diameter. Both surfaces are sparsely to densely pubescent. Small, yellow, pealike flowers are borne in both terminal and axillary clusters. Pods are about ½ inch long and densely hairy.

Dollarleaf rhynchosia is readily distinguishable from related species and most other plants by its large, round, simple leaves. Young plants are grazed by cattle, and seeds are eaten by quail and other birds.

Range: Texas to Florida, extending north to North Carolina.

Perennial. **Stems** erect, densely pubescent, from long slender rhizomes, 5 – 25 cm tall, hirsute on the angles with spreading or reflexed hairs; **leaves** simple, the blades 2 – 5 cm long, 2 – 8 cm broad, orbicular to reniform, strongly reticulate, resin-dotted with appressed pubescence on veins; **flowers** in short, dense axillary or terminal racemes 2 – 3 cm long; **calyx** 8 – 10 cm long; **corolla** yellow, about 7 mm long; **legume** flat, oblong, about 1.5 cm long, and 6 mm wide, obscurely falcate, pubescent, resin-dotted; **seeds** lenticular, about 3 mm broad, brownish, mottled with black.

Catclaw Sensitivebrier—*Schrankia uncinata* Willd.—(*S. nuttallii* (DC.) Standl.)



Catclaw sensitivebrier is a close relative of the silktree, *Albizia julibrissin* Duraz., commonly called "mimosa," and the acacias. Its spherical rose pink flower heads resemble miniature silktree heads.

Catclaw sensitivebrier is a spiny, sprawling, perennial herb usually found on dry sandy soils west of the Mississippi River. Many prostrate stems 3 to 4 feet long arise from a large woody rootstock. Flowering begins in late spring and continues through the summer, or as long as stem growth continues. Leaves are bipinnately compound, with four to eight pairs of first-division units, called pinnae. Each pinna has 8 to 15 pairs of oblong to elliptical leaflets ⅛ inch to over ¼ inch long which fold when touched.

A similar species, *Schrankia hystricina* (Britt. & Rose) Standl., with a stout, bristly pod no longer than 1½ inches, apparently replaces catclaw sensitivebrier in east Texas and southwest Louisiana. Another sensitivebrier likely to be encountered southwide is littleleaf sensitivebrier, *S. microphylla* (Dryand.) Macbr. These species differ primarily in leaflet venation; both *S. uncinata* and *S. hystricina* have conspicuous lateral veins, but littleleaf appears to have only a midrib.

Cattle graze the tender twigs in early spring before the spines harden. Nutritive value is high; protein content of new growth reportedly reaches 45 percent. Plants are seldom abundant enough to contribute greatly to the cattle diet. This species is generally considered more important as an indicator of good or improving range condition than as a forage producer. Deer browse the stems and leaves, and quail eat the seeds.

Range: Texas to Alabama, extending north to Nebraska, Illinois, and North Carolina.

Perennial. **Stems** elongate, decumbent, angled, prickly, to 1 m long; **leaves** bipinnate, 6 – 15 cm long, sensitive; **pinnae** 4 to 8 pairs, 2 – 5 cm long; **leaflets** 8 to 15 pairs, oblong-elliptic, 3.5 – 9.0 mm long, veins prominent; **flowers** in spherical, long-peduncled, axillary heads 2.0 – 2.5 cm in diameter; **pods** linear, strongly thorny-ribbed, 4 – 12 cm long, with a slender beak at the apex.

Perennial Wildbean—*Strophostyles umbellata* (Muhl. ex Willd.) Britt.

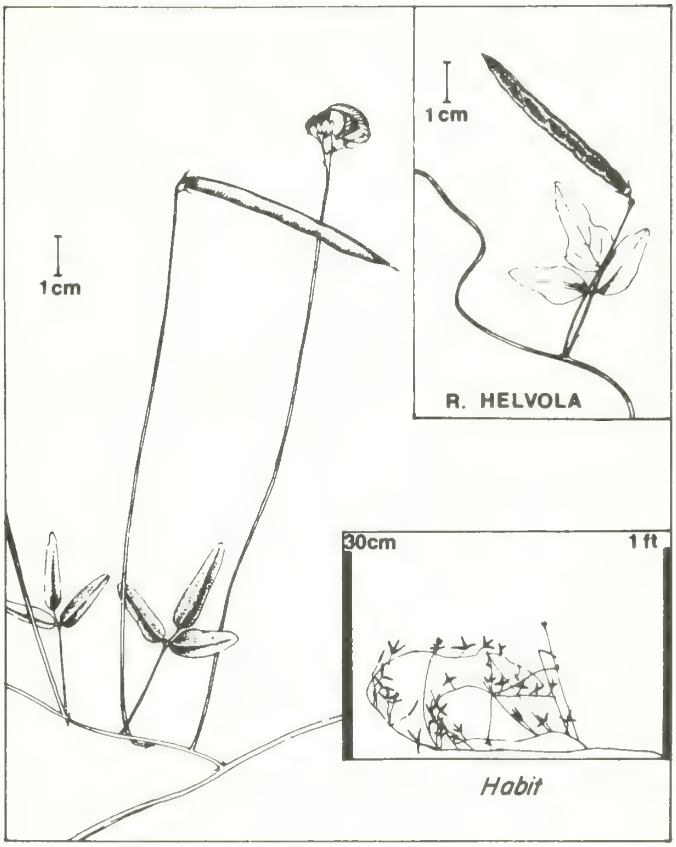
The wildbeans are trailing herbaceous vines whose seeds are considered desirable wildlife food, especially for bobwhite quail and turkey. Perennial wildbean is classified as a choice wildlife food plant. Two annual species, trailing wildbean, or amberique bean, *Strophostyles helvola* (L.) Ell., and slickseed wildbean, *S. leiosperma* (T. & G.) Piper, are not as highly valued, perhaps due to a general lack of abundance.

Perennial wildbean grows on sandy soils of the pineywoods, usually twining among the grasses and other ground vegetation. It is conspicuous by its unlobed trifoliolate leaves with narrowly ovate to lanceolate or oblong leaflets and elongate inflorescence stalks, which exceed the leaves. Flowers have a short ribbed bractlet at the base of the calyx.

Trailing wildbean has broader leaflets, usually with basal lobes. It commonly grows on open sites along rivers but may be found growing with perennial wildbean. The inflorescence stalks, similar to those of perennial wildbean, are usually longer than 6 inches. The floral bractlet is about equal in length to the calyx.

Slickseed wildbean is a smaller, hairier species found from Alabama westward to the plains of Texas and northward to Colorado, Minnesota, and Indiana. Inflorescence stalks are less than 4 inches long.

Range: Texas and Oklahoma to Florida, extending north to southern New York.



Perennial. **Stems** trailing or twining, to 2 m long, the younger portion densely pubescent; **leaflets** ovate, lanceolate to elliptic or oblong, unlobed, 2 – 5 cm long, glabrous or nearly so; **racemes** axillary, peduncles 10 – 25 cm long with few to several capitately clustered flowers; **calyx tube** 2.0 – 2.5 mm long, subtended by obtuse, striate bracts 0.1 mm long or less; **corolla** pink or pale purple, often fading yellowish, the standard 1.0 – 1.4 cm long; **legume** sparsely appressed-pubescent, 3.0 – 6.5 cm long, about 4 mm broad; **seeds** 3 – 6 mm long.

Pencilflower—*Stylosanthes biflora* (L.) BSP.

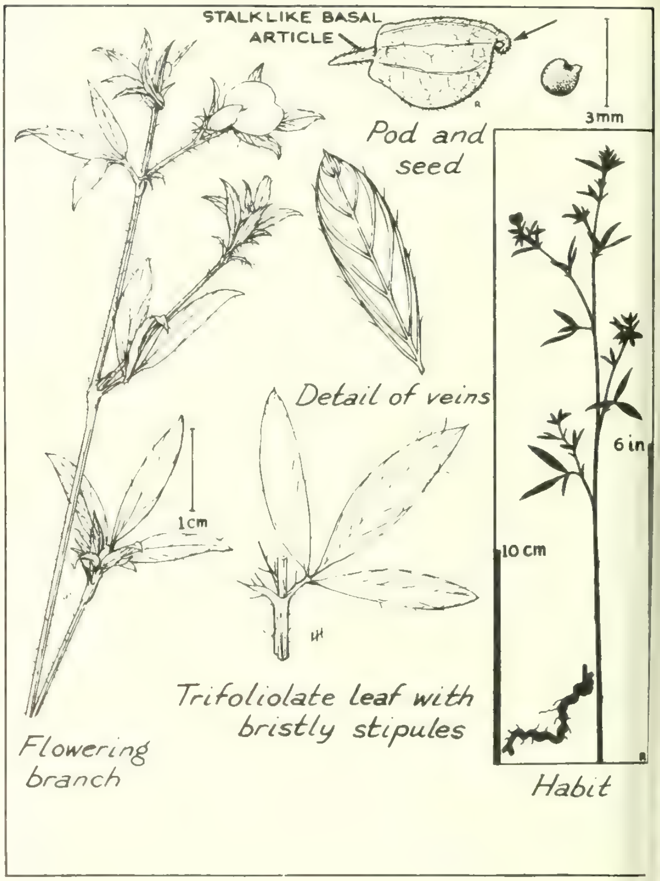
Pencilflower is a small perennial, common on well-drained sites throughout the South. Plants vary widely in height, branching habit, size and shape of leaflets, and hairiness.

Plants seldom exceed 12 inches in height, and are inconspicuous except for the pencil-yellow pealike flowers that appear throughout the growing season. Flowers, ¼ to ½ inch long, are in short, tight spikes at branch tips. Pods are small and inflated, with a sterile, stalklike basal article. Leaves are trifoliolate with elliptical leaflets about ¾ inch long.

Without flowers, pencilflower resembles other small-leaved legumes, especially lespedezas and tickclovers. It is distinguishable, however, by leaf characters, the veins on the underside of the leaflets being distinctly lighter in color than the blade and conspicuously thickened. Veins of lespedezas and tickclovers are relatively slender, and their color resembles that of the blade.

The seeds are eaten by quail and turkey. The leaves and stems are nutritious and palatable to cattle, but plants are small and usually widely scattered, and forage yield thus is negligible.

Range: Texas to Florida, extending north to Kansas, Illinois, Indiana, and New York.



Perennial. **Stems** 10 – 40 cm tall, stiff, erect, branching or unbranched, finely pubescent to long-hirsute, often bristly at the summit; **leaves** trifoliolate; **stipules** sparsely to densely bristly, narrow, united with the petiole for about two-thirds of their length; **leaflets** narrowly lanceolate to elliptic, subulate-tipped, 1.5 – 4.0 cm long, margins entire to bristly ciliate; **flowers** papilionaceous, on a stalklike hypanthium; **calyx** glabrous, early falling; **corolla** yellow with pink veins on the back; **fruit** a loment, 4 – 5 mm long with one to two articles, the terminal one turgid, thinly hairy, reticulate with an incurved beak (style), the basal one undeveloped, stalklike.

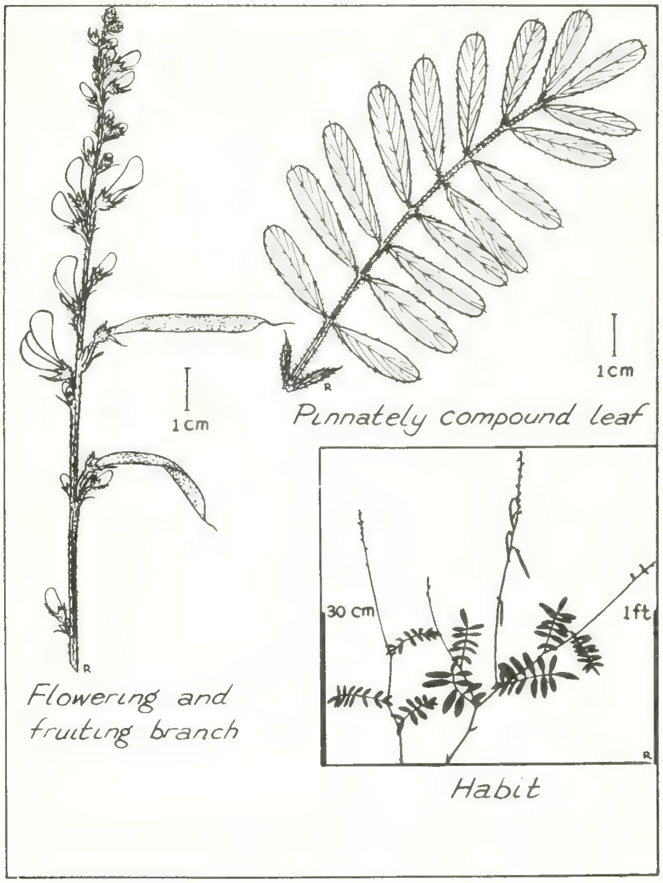
Weak Tephrosia—*Tephrosia onobrychoides* Nutt.

Weak tephrosia is a reclining perennial that grows from a woody rootstock. It is common on sandy soils of the western Gulf Coastal Plain. Stems may branch several times, with each branch terminated by an elongate stalk of white to reddish-purple flowers. The upper half of the stalk is leafless. Flowers normally appear in May or June, and continue flowering into August if rainfall is adequate. The flat, hairy pods, 2 inches long or less, have up to 10 small black seeds. Leaves are pinnately compound with 11 to 25 linear-oblanceolate leaflets.

Weak tephrosia's range overlaps that of brownhair tephrosia from southeast Louisiana to Alabama. Foliage of weak tephrosia is grayish green in color and the "weak" flower stalks do not stand stiffly erect as do those of brownhair tephrosia. As its name implies, the pubescence of brownhair tephrosia is noticeably more rust colored, and the leaves average fewer (9 to 17) leaflets.

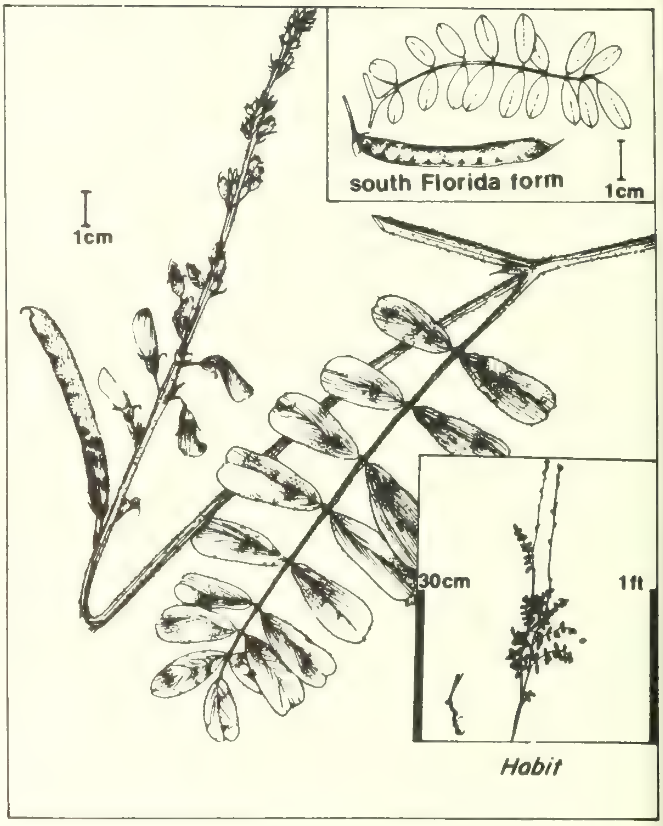
Cattle graze young growth on recently burned or heavily used range, but older foliage is usually rejected. Seeds are eaten by quail.

Range: Texas to Oklahoma to southern Missouri and Alabama.



Perennial. **Stems** pubescent to strigose with rusty hairs, erect to decumbent from a stout, woody crown and woody taproot; **leaves** odd-pinnate, 8 – 22 cm long, on a petiole 7 – 35 mm long; **leaflets** of the principal leaves 11 to 25, linear-oblanceolate and slightly broadened upward, 1.5 – 5.5 cm long, 4 – 16 mm wide, the apex obtuse, rounded or truncate, emarginate, glabrous to pubescent above, more or less silky-pilose with gray to rusty hairs beneath; **flowers** 15 – 20 mm long in long terminal or axillary racemes much exceeding the foliage; **corolla** white, becoming crimson in age, pink or purple upon drying; **legumes** straight or slightly curved downward, 3.5 – 5.0 cm long, 4 – 5 mm wide, pubescent; **seeds** 3 to 10, 3 – 5 mm long, smooth and mottled with black.

Brownhair Tephrosia—*Tephrosia spicata* (Walt.) T. & G.



Stems of brownhair tephrosia arise from a woody taproot and may be erect to 2 feet tall, or they may be sprawling. Stems and leaflet lower surfaces are rust colored and covered with spreading tawny hairs. Like other tephrosias, brownhair is not classed as valuable forage or wildlife food; bobwhite quail and other birds eat the seeds, but its general lack of abundance limits its value.

Brownhair tephrosia is most common east of the Mississippi River. Although its geographic range overlaps that of weak tephrosia, the two species are seldom found growing together. Leaflets of brownhair are generally larger and fewer in number than those of weak tephrosia. The reddish-brown color of the stem and lower leaf surface is more pronounced in brownhair tephrosia.

In south Florida, brownhair tephrosia grows in dwarf clumps about 1 foot in diameter. Leaves and leaflets are about half the size of those of typical plants, and lower leaf surfaces are reddish brown in color, although plants of the south Florida form are generally less hairy. This form was formerly separated as var. *semitonsa* Fern. by some authors.

Range: Louisiana, eastern Tennessee, and Kentucky to southern Delaware, southeastern Virginia, and Florida.

Perennial. **Stems** 30 – 60 cm long, decumbent to erect from a cylindric taproot, densely pilose or occasionally sparsely appressed-pubescent; **leaves** 4 – 12 cm long; **leaflets** 9 to 17, oblong-obovate to obovate or elliptic, 1 – 3 cm long, 6 – 14 mm wide, glabrous to finely pilose above, somewhat appressed pubescent to pilose below; **inflorescences** appearing opposite the leaf or terminal, 4 – 60 cm long, usually longer than the nearest leaf, erect or upwardly curving, pedicels 1 – 8 mm long; **calyx** 6 – 7 mm long, sparsely pilose to villous; **petals** at first white, turning pink and then carmine, 1.2 – 1.7 cm long; **stamens** diadelphous; **legumes** 3 – 5 cm long, 4 – 6 mm broad, sparsely to moderately pubescent.

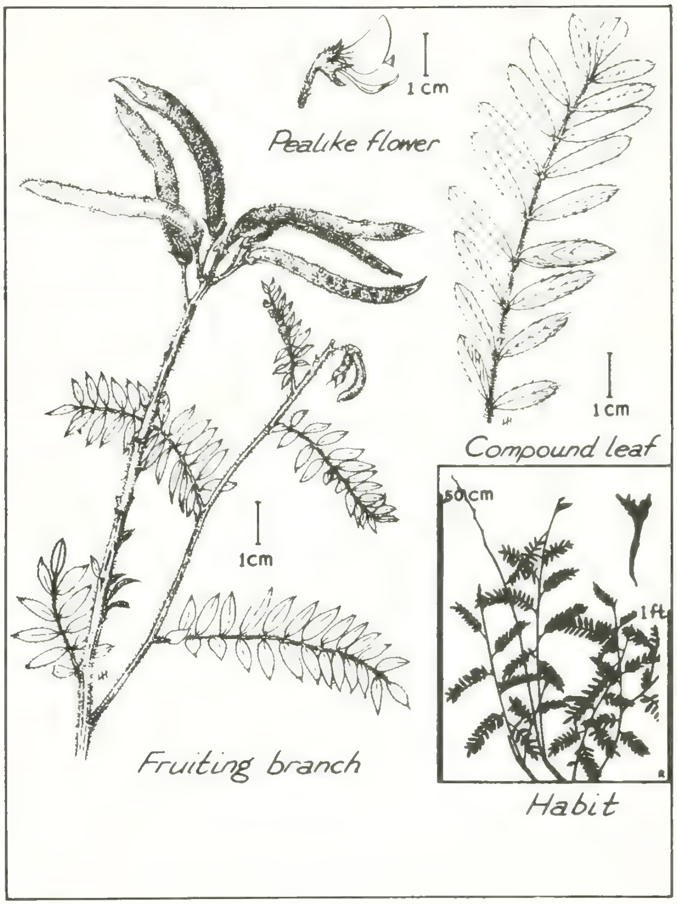
Virginia Tephrosia—*Tephrosia virginiana* (L.) Pers.

Virginia tephrosia—also called catgut, goatsrue, or devils-shoestring—is often the most abundant forb on dry sandy sites that are periodically burned. Following fire, new shoots grow rapidly from woody rootstocks. Although leaves are similar to those of the partridgepeas, pinnate with from 11 to 27 leaflets, they end in a single leaflet (odd-pinnate), while partridgepea leaflets are evenly paired throughout (even-pinnate). Stems and the undersides of leaflets, especially on new growth, are densely coated with gray hairs. Plants may reach 20 inches in height and often grow in clumps up to 30 inches in diameter. Flowers are produced in terminal clusters in spring, but spring or summer burning may prolong flowering. The corolla of the pealike blossom consists of one cream to yellow petal and three rose petals. Pods are about 2 inches long and covered with gray hair.

Virginia tephrosia often grows in association with weak or brownhair tephrosia, or one of the other eight species recognized across the South. It is the only species, however, with erect simple stems and terminal inflorescences, and is usually found on drier sites than most other tephrosias.

Cattle rarely eat Virginia tephrosia, even on heavily grazed range. The seeds rate fair as quail food, being taken mainly when other food is scarce.

Range: Texas to Florida, extending north to Minnesota and Massachusetts.



Perennial. **Stems** 30 – 60 cm tall, pubescent to villous, erect or ascending from a branched woody crown and long woody roots; **leaves** odd-pinnate, 6 – 10 cm long, nearly sessile; **leaflets** 11 to 27, elliptic to linear-oblong, 1 – 3 cm long, 4 – 8 mm wide, apex mucronate; **flowers** papilionaceous, bicolored; **racemes** compact, 4 – 8 cm long, leafy in the lower flowering nodes; **standard** 14 – 21 mm long, lemon yellow to cream, wings and keel rose; **legumes** 3 – 5 cm long, straight to slightly curved, sparsely to densely strigose; **seeds** 6 to 11, bean shaped, 3.2 – 4.2 mm long, brown variegated with black.

Composites

The composites—plants of the family Compositae (or Asteraceae)—are well known for their showy flowers. Chrysanthemums, asters, daisies, and zinnias are among the popular ornamentals. Many native composites—sunflowers, goldenrods, and coneflowers, for example—are also colorful. Although composites are mainly herbaceous, the family includes several woody species. These are represented in the South by the shrubby genus *Baccharis.*

The characteristic composite "flower" is actually a compact head of small, sessile flowers crowded on a common receptacle and surrounded by overlapping bracts. The corollas are of two general types: the five-lobed tubular type, or disk flower; and the flat, ligulate type, or ray flower. Singly, or in combination, disk and ray flowers produce three types of heads: the **discoid**, with only tubular or disk flowers, represented by the gayfeathers; the **ligulate**, with only ligulate or ray flowers (usually with a "milky" sap), such as the dandelions; and the **radiate**, with a central disk of tubular flowers surrounded by a radiating ring of ray flowers, exemplified by the sunflower or coneflower head.

Composites are prolific seeders, and the seeds or fruits of many are easily transported by the wind. Hence, these plants are generally more abundant than other forbs, especially on denuded sites where seeds easily reach mineral soil.

On open pine-bluestem range, composites contribute up to 3 percent of the yearlong diet of cattle. While several species are valuable as forage, many are worthless. A few species, such as bitter sneezeweed, are poisonous.

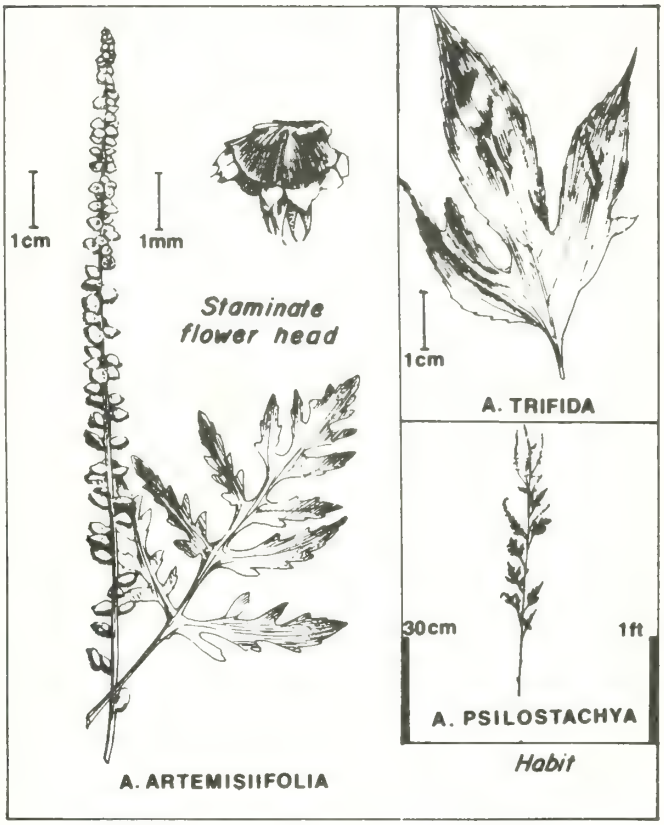
Ragweeds—*Ambrosia* spp.

On moist sites throughout the South, especially road ditches, annual plants of common ragweed, *Ambrosia artemisiifolia* L., may form dense stands with stems up to 8 feet tall. Foliage, especially when crushed, is very pungent. Lower leaves are opposite, becoming alternate above; blades are ovate in general outline but deeply twice- or thrice-divided. Flowers and seeds are produced on stalks arising from upper leaf axils from late summer until frost. Staminate flowers in numerous saucer-shaped heads about ⅛ inch wide terminate the flower stalks. Pistillate heads, fewer in number and below the staminate heads, are enclosed in foliaceous bracts. Fruits are about ⅛ inch long.

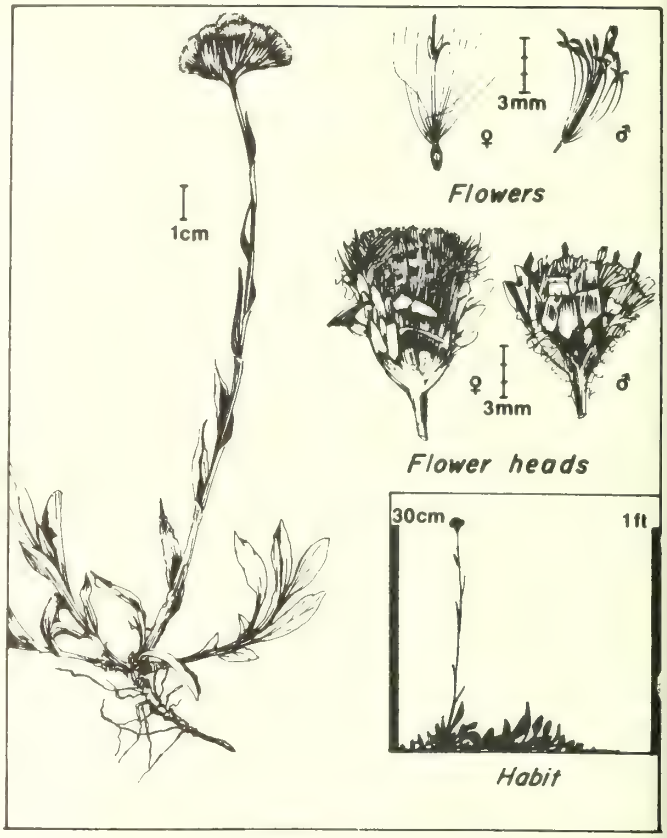
Western ragweed, *A. psilostachya* DC., a smaller perennial of drier sites in the western gulf coast and prairies, is similar, but the leaves are thicker and only once-divided. Giant ragweed, or richweed, *A. trifida* L., similar to and as widespread as common ragweed, is also an annual, usually on wetter sites than other ragweeds, and may grow 20 feet tall. Its opposite, palmately three- to five-lobed leaves distinguish it from all other ragweeds. Lanceleaf ragweed, *A. bidentata* Michx., another annual found on pinelands, has narrow leaves with a broad base and two lateral lobes, each terminated by a tooth.

Ragweed foliage is normally unpalatable to cattle, but when forage is scarce, it is sometimes eaten, producing a bitter taste in the milk. Plants sprayed with 2,4-D become palatable and accumulate nitrates in toxic amounts (Kingsbury 1964). Common ragweed is a high-use forage plant for white-tailed deer in spring and summer. Deer also eat the leaves of giant ragweed, and seeds of all three species discussed above are eaten by wild turkey and other birds. Ragweed seeds are one of the most important quail foods in volume consumed.

All ragweeds are considered principal contributors to hay fever suffering throughout the South.



Plantainleaf Pussytoes—*Antennaria plantaginifolia* (L.) Richardson



Flowers

Flower heads

Habit

Other names for this small attractive composite are ladies-tobacco and indian-tobacco. It is similar and closely related to the cudweeds *(Gnaphalium* spp.). Plants are most common on dry sandy or rocky soils in open woods or thickets. Runners just below the soil surface produce a loose clump of stems 4 to 15 inches tall. Male and female flowers are borne on separate plants; female plants are taller than male plants. When all stems in a clump arise from runners of a single plant, all flowers are of the same sex.

Except for a basal whorl of paddle-shaped leaves about 2 inches long and 1 inch wide, foliage is scant. Leaves on the stalk are about 1¼ inches long and ¼ inch wide near the base, becoming gradually smaller up the stalk. Stem and leaves are coated with short gray hair.

Stalks are unbranched and terminated by a cluster of many-flowered heads, each about ¼ inch in diameter. White-tipped bracts, resembling petals, surround each head. Pappus bristles surrounding each flower are also white-fringed. Floral parts and involucral bracts often add a reddish or purplish tinge to the otherwise white flower head.

Seeds of plantainleaf pussytoes are small and of little value to wildlife. The rosette leaves, which form in the fall and remain green through the winter, are eaten by deer. Of several species occuring in the South, plantainleaf is the most common and the only one recognized valuable to wildlife.

Range: Texas to Minnesota and eastward.

Perennial. **Stems** from stolons; **pistillate stems** 10 – 40 cm tall, **staminate stems** about 15 cm tall; **basal leaves** 5 – 9 cm long, obovate, mucronate, minutely canescent above, densely so below, 3- to 7-nerved; **cauline leaves** alternate, spatulate below, lanceolate or linear above, crowded below and about 4 cm long, becoming remote above and less than 2 cm long; **flower heads** 3 to 30, corymbose to glomerulate, 10 mm or less in diameter; **pistillate flowers** about 7 mm high with glands on corolla tube; **staminate flowers** less than 5 mm, staminate pappus with white, thickened tips; mature **achenes** 4.0 – 5.5 mm long.

Asters—*Aster* spp.

With approximately 100 species, the asters comprise the largest southern genera of composites. Most are perennials, blooming in late summer and fall; some produce flowers until the first frost. Though seldom found growing in profusion, the asters provide rich fall color to the southern woodlands.

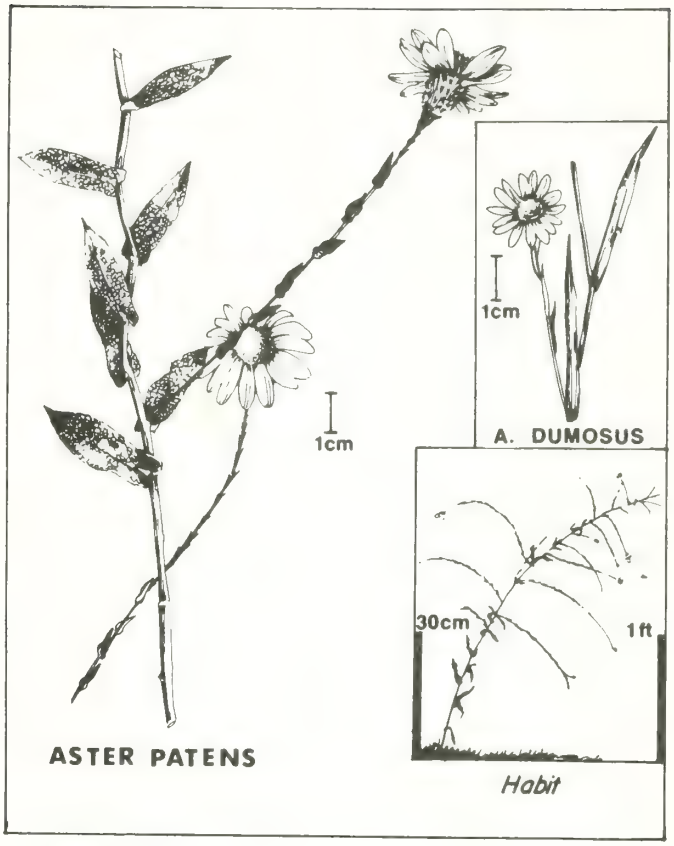
Characteristic flower heads consist of a central disk of tubular yellow flowers surrounded by a whorl of white, blue, or pink to purple ray flowers. The base of the flower head is enclosed by several overlapping whorls of bracts. Several of the most common southern asters are described below.

Skydrop aster, *Aster patens* Dryand. in Ait., is common in dry open woodlands and clearings from Texas and Florida to Minnesota and Maine. Height is 3 feet or less. The main stalk of the plant has ovate-elliptical leaves 1 to 2 inches long, with bases clasping the stem. Lateral branches, arising from upper leaf axils, have leaves much smaller than those of the main stalk. Flower heads are about 1 inch wide, with purplish rays.

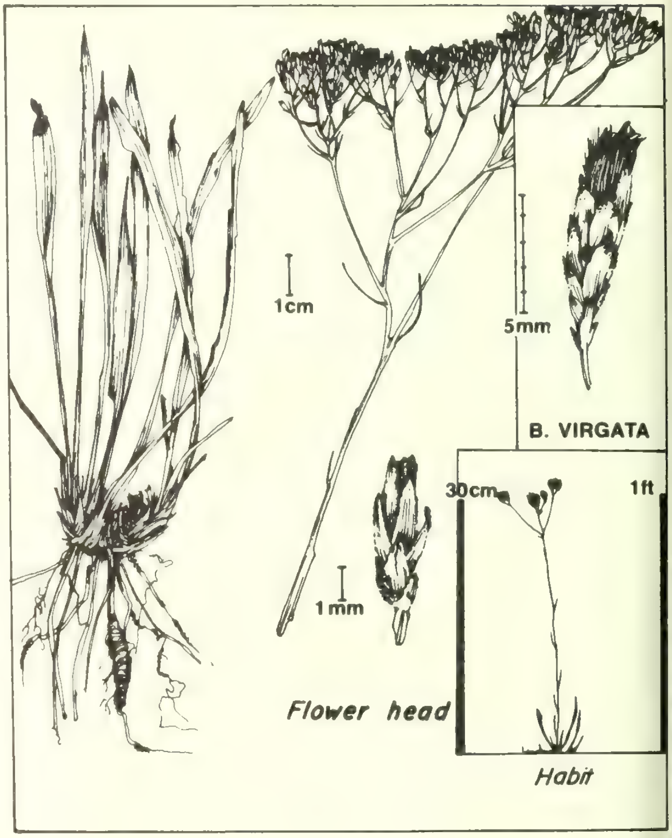
Silver aster, *A. concolor* L., inhabits sandy pinelands east of the Mississippi River and inland to Kentucky. Its flowers are similar to those of skydrop aster but are arranged in racemes terminating ends of unbranched stems. Plants are seldom more than 2 feet tall. Leaves are elliptic-oblong to lanceolate, up to 1½ inches long. Stems and leaves are somewhat silky pubescent.

Bushy aster, *A. dumosus* L., grows to a height of about 3 feet on a wide range of soils from Louisiana north to Missouri and Maine. Flower heads are ½ to ¾ inch wide, white to pale purple, scattered on the profuse branches of the upper stem.

Because they are not generally abundant, asters are practically worthless as cattle forage. As a group, however, they are preferred food for deer, which eat the basal rosettes from autumn into spring and the stems and flowerheads in summer and early autumn. Although most abundant and robust on disturbed sites, asters are not uncommon in stable plant communities on both timbered and cutover range.



Yellowhead—*Bigelowia nudata* (Michx.) DC.—*(Chondrophora nudata* (Michx.) Britt.)



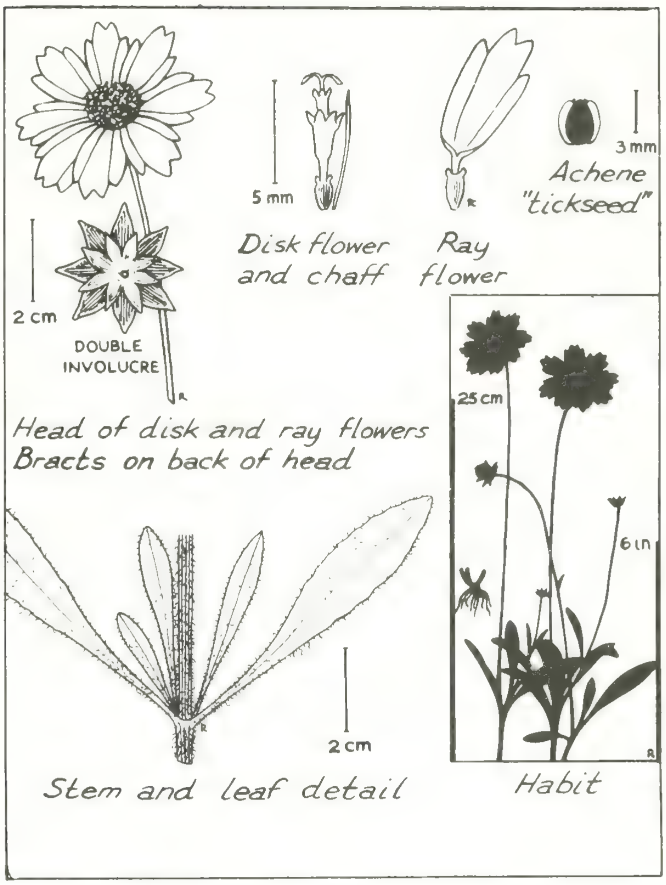
Also called rayless goldenrod and naked chondrophora, this plant occurs on a wide range of soils and sites, from deep acid sands to shallow calcareous soils. It is most abundant on wet prairies of the pine-wiregrass flatwoods. On sandy pine uplands, it occurs infrequently, but is found in colonies, spreading by rhizomes. Yellowhead is a slender perennial 1 to 2 feet tall with alternate, spatulate leaves 2 to 3 inches long and $^{1}/_{16}$ inch or less wide. Basal leaves may form an early rosette or whorl, and may be slightly longer and wider than stem leaves, which decrease in size going up the stem. By flowering time, however, the outer portions of leaves usually break off, leaving only narrow petiolar stubs. Stems are unbranched below the flat-topped inflorescence. The narrow, essentially bare stems, topped by greenish-yellow heads of flowers, give this plant a conspicuous and unique appearance.

A closely related species, *Bigelowia nuttallii* L. C. Anderson *(B. virgata* (Nutt.) DC.), is similar but has much finer, almost hairlike, leaves. Neither plant is valuable as livestock forage or wildlife food.

Range: Coastal Plain, Texas to Florida and Virginia.

Perennial. **Stems** from woody caudex or rhizome, glabrous, 20 – 80 cm tall; **basal leaves** spatulate to linear-spatulate, 3 – 12 cm long, 2 – 6 mm wide at widest point; **stem leaves** few, alternate, smaller than basal leaves, reduced upward, blades early-deciduous; **inflorescence** a flat-topped corymb of numerous flower heads (involucres); **heads** cylindrical, 3- to 5-flowered, 5 – 6 mm long, 1 – 2 mm broad, flowers all discoid, yellow; **achenes** turgid, tapered from base to apex, 1.2 – 1.5 mm long, pubescent.

Thickleaf Coreopsis—*Coreopsis lanceolata* L.



Thickleaf coreopsis, or "tickseed" as all species of *Coreopsis* are also called, grows on a wide variety of sites. Though rarely abundant, plants are conspicuous by their naked flower stalks and bright yellow flowers.

Mature stems are usually less than 15 inches tall. Stems and leaves are generally covered with downy to stiff hairs. Leaves are opposite, narrow to broadly lance shaped, and largely confined to the lower half of the stalk. Early leaves form a basal rosette; with their long, slender petioles, they often exceed 6 inches in length. Upper leaves are without petioles and are distinctly smaller than the lower.

Flowering begins in April and continues through the growing season. Heads have yellow disk and ray flowers and are about 2 inches in diameter. The toothed ray flowers are about ¾ inch long.

Immature plants of lanceleaf gaillardia, *Gaillardia aestivalis* (Walt.) H. Rock, resemble those of thickleaf coreopsis, but are distinguishable by their alternate leaves. After flowers appear, differentiation is easy, as the disks of lanceleaf gaillardia are reddish purple.

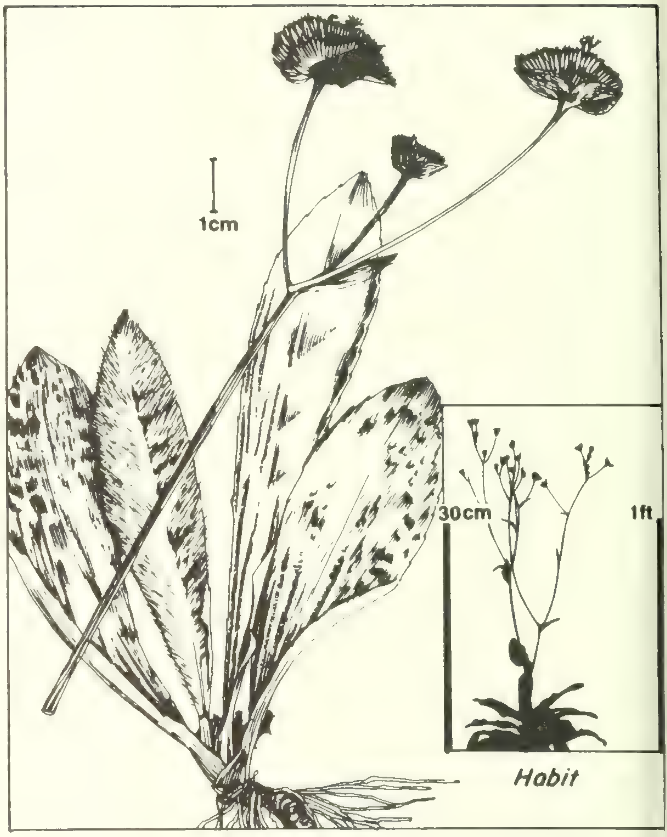
Thickleaf coreopsis is of little value to livestock or game animals. Other species common on southern pine range include *C. gladiata* Walt., with narrow oblanceolate leaves associated with wet sandy sites; *C. major* Walt., with opposite, sessile, ternately divided leaves appearing as whorls of leaves at the upper nodes; and *C. tripteris* L., with three to five palmately divided leaves on petioles about 1 inch long.

Range: Texas and Louisiana to Florida, extending north to Wisconsin, Michigan, and Virginia.

Perennial. **Stems** 20 – 60 cm tall, from a woody caudex, branching near the base, glabrous, pubescent, or villous; **leaves** mostly basal and petiolate, 5 – 20 cm long, 10 – 17 mm wide, lance-linear to spatulate, entire, opposite, glabrous to villous; **heads** 4 – 6 cm broad, radiate, solitary, on elongate, naked peduncles; **involucre** double, the outer bracts linear-lanceolate, 6 – 8 mm long, the inner ovate, 0.8 – 1.3 cm long; **disk** 1 – 2 cm broad, deep yellow orange, slightly convex; **disk flowers** on a flat, chaffy receptacle, 5 – 7 mm long, fertile; **rays** eight, 15 – 30 mm long, 5 – 10 mm wide, cuneate to obovate, deeply 4-toothed, brilliant yellow, sterile; **achenes** 2.5 – 3.0 mm long, compressed, orbicular, with thin, flat wings; **pappus** of two minute, chaffy teeth.

Hairy Elephantfoot—*Elephantopus tomentosus* L.

The name of this plant was inspired by a fancied similarity of the large, prostrate basal leaves to an elephant footprint. Basal leaves, which are elliptic to obovate and up to 12 inches long and 4 inches wide, are produced in early spring from a woody root crown. Essentially leafless, branched flower stalks up to 2 feet tall are produced from mid-summer to early fall. Not more than one node and leaf is produced on a stalk above the basal leaves. The entire plant is densely hairy. The stalk is terminated by a branching inflorescence, each branch with a terminal cluster of purplish tubular flowers. Flower clusters are subtended by three ovate leaf-like bracts, and small bracts subtend each branch of the inflorescence.



Hairy elephantfoot is common throughout the Piedmont and Coastal Plain on a wide range of sites, from bottomlands to sandhills. It is perhaps most important as forage in open pine forests on flatwoods sites of the longleaf-slash pine wiregrass type, but is rated only fair at best. Because most of its foliage is at ground level, it can tolerate heavy grazing.

Leafy elephantfoot, *Elephantopus carolinianus* Raeusch., is common throughout the range of hairy elephantfoot but is usually on wetter sites. Unlike hairy elephantfoot, it has stem leaves and no basal leaves. *Elephantopus nudatus* Gray and *E. elatus* Bertol, are also common, resembling hairy elephantfoot but with somewhat smaller flowers and flower heads.

Range: Texas to Florida, Tennessee, and Virginia.

Perennial. **Stems** one to five, from a woody crown, 20 – 90 cm tall, hirsute, subscapose, nodeless, or one node below the first inflorescence branch; **leaves** mostly basal, elliptic to obovate, densely pilose to tomentose, 3.0 – 10.5 cm wide, 8 – 22 cm long, **inflorescence** a loosely branched corymb, involucres cylindric, 10 – 14 mm long, densely pubescent, subtended by three ovate foliar bracts; **flowers** all discoid, three to four per head, pinkish to purple.

Daisy Fleabane—*Erigeron strigosus* Muhl. ex Willd. var. *beyrichii* (Fisch. & Mey.) T. & G. ex Gray

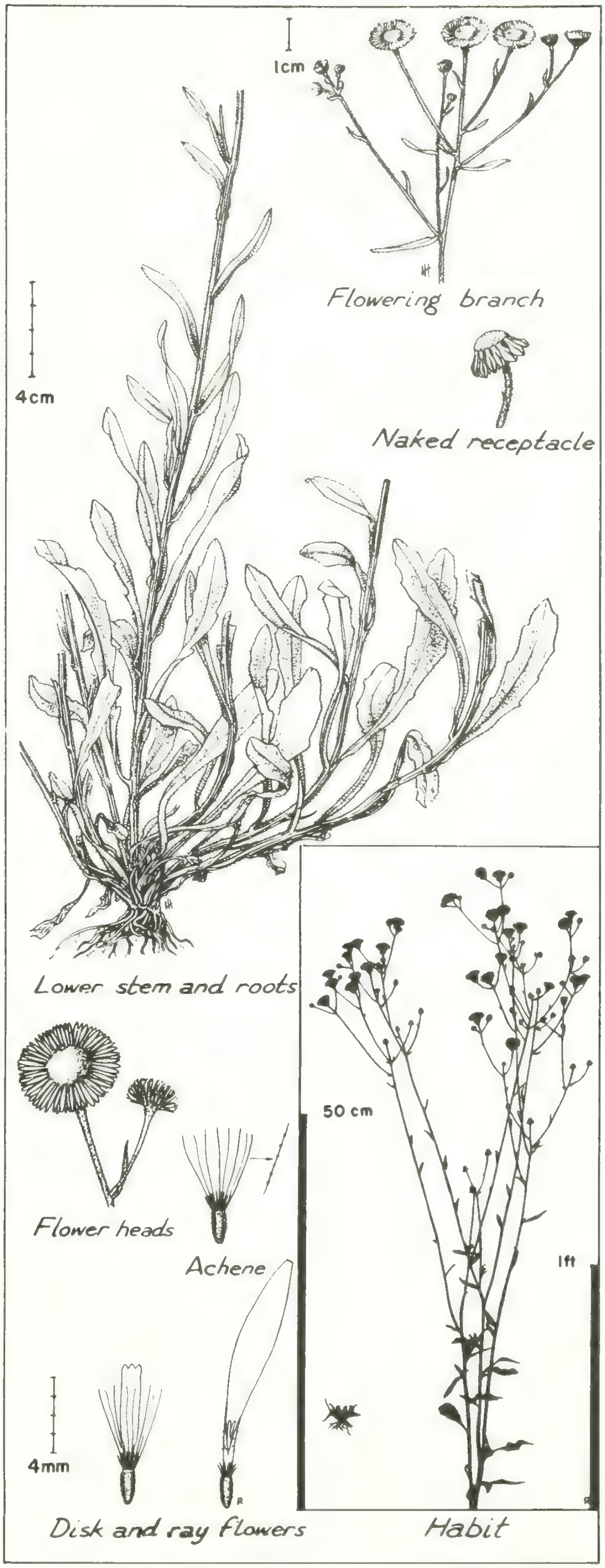
Like most annual composites, daisy fleabane is most abundant on old fields, roadsides, firelines, and other open, disturbed areas. It is common on undisturbed range, however, even under moderately dense timber. Sandy soils apparently provide the best habitat.

Plants may reach a height of 3 feet or more where competition is light, but where grass is dense, height seldom exceeds 2 feet. Early spring leaves, which form a basal rosette, are coarsely toothed. They are 6 inches long and 1 inch wide, with the greatest width in the upper one-third. Leaves on the upper stem are smaller—1 to 3 inches long and less than ½ inch wide—and without toothed margins. Leaves and stems are sparsely covered with short, stiff, ascending hairs that make plants rough to the touch.

The inflorescence consists of several to many daisylike flower heads, ⅝ inch or less in diameter. Each head has an outer ring of ray flowers and an inner disk of tubular flowers. The ligules of the ray flowers are about ¼ inch long and usually white, though occasionally the outer may be bluish or pink. Yellow flowers make up the central disk, which is about ⅜ inch in diameter. Flowering may begin in mid-April and continues through midsummer. Both ray and disk flowers produce a two-nerved achene less than 1/16 inch long.

Prairie fleabane, *Erigeron strigosus* Muhl. ex Willd. var. *strigosus*, is also an annual, rarely a biennial. It is a larger plant with larger, more showy flower heads, but is seldom found on grazed southern forest range. Several recent authors "lump" both varieties under *E. strigosus* Muhl. (Radford and others 1968, Correll and Johnson 1970). Other spring-flowering biennial or perennial fleabanes common southwide include *E. philadelphicus* L., a robust plant with toothed or divided, oblanceolate lower leaves, and *E. pulchellus* Michx., with mostly basal leaves and the few stem leaves reduced in size toward the tip of the usually unbranched stem, which is terminated by one to several showy flower heads. *Erigeron tenuis* T. & G., which is not found east of the Mississippi River, is a slender plant with oblanceolate, shallowly lobed leaves and several branches forming a more or less flat-topped inflorescence.

The annual horseweed, or horsetail conyza, *Conyza canadensis* var. *pusilla* (Nutt.) Cronq. *(E. pusillus* Nutt.), is a common roadside weed throughout the South. It has numerous narrow leaves gradually reduced in size going up the usually unbranched stem, with the lower, broader leaves falling early. Flower heads are small, numerous, and in a long, open



inflorescence. Plant height may exceed 6 feet on disturbed sites. *Conyza canadensis* (L.) Cronq. var. *canadensis (E. canadensis* L.) is widespread in the eastern U.S. but is not common on the Coastal Plain.

Cattle graze daisy fleabane in the spring before flowers form. On some sites, plants are abundant enough to contribute considerable forage. Nutritive value of young plants is high. In summer, deer may browse the flowers and upper stems of several fleabanes.

Range: Texas to Florida, extending north to Rhode Island, then west to Washington.

Annual. **Stems** strigose, 20 – 100 cm tall; **basal leaves** oblanceolate to elliptic, entire or toothed, petiolate, up to 15 cm long and 2.5 cm wide; **upper leaves** linear to lanceolate, minutely strigose to glabrous, entire, alternate, sessile; **inflorescence** corymbose, of few to many heads; **heads** 5 – 15 mm in diameter; **bracts** 2 – 3 mm long, linear-lanceolate, scarious margined; **disk** 9 mm or less in diameter, flowers perfect; **ray flowers** pistillate, rays 6 mm long or less, white to bluish or pink; **achene** 2-nerved, angled, about 1 mm long.

Eupatoriums—*Eupatorium* spp.

The eupatoriums, along with asters and goldenrods, are the most common composites in the southern United States. Several species grow on ranges in good condition; others occur mainly as invaders of disturbed sites. In general, eupatoriums have little grazing value; at least one species, white snakeroot, is poisonous to livestock. The seeds of several eupatoriums are eaten by birds.

The many-branched inflorescence is composed of numerous heads in flat-topped, rounded, or conical arrangements. In the most common species on southern pine forest range, flowers are tubular, white, and about ¼ inch long. Heads are enclosed at the base by a whorl of greenish bracts, which in some species have whitish margins and tips. Most eupatoriums have fewer than 10 flowers per head, but some have up to 70. Each corolla is surrounded and almost hidden by an early developing ring of hairs, or pappus, which acts like a parachute to aid in wind dissemination of the fruit (achene).

Most eupatoriums flower in late summer or fall; hence recognition during most of the growing season must depend on vegetative differences. Intergradation is common among associated species. The following key may aid in the identification of several common species by foliage characteristics. All plants are perennials and flower color is white unless another color is specified. Descriptions of four species follow the key. The four species, which illustrate the range in leaf shapes and inflorescence types in *Eupatorium*, are white eupatorium, *E. album* L.; dogfennel, *E. capillifolium* (Lam.) Small; hyssopleaf eupatorium, *E. hyssopifolium* L.; and roundleaf eupatorium, *E. rotundifolium* L.

Key to Eupatoriums

1. Leaves dissected into narrow segments, opposite and alternate on same plant; inflorescence conical 2
1. Leaf margins toothed but not dissected, leaves opposite; inflorescence more or less flat topped 3
    2. Leaf segments hairlike; plant tops lax, slightly drooping .... *E. capillifolium* (Lam.) Small, dogfennel (page 100)
    2. Leaf segments flat, often ⅛ – ¼ inch (3 – 6 mm) wide; plant tops erect .... *E. compositifolium* Walt., yankeeweed
3. Length of typical leaf blade less than twice the width 4
3. Length of blade 2 or more times the width 5
    4. Blades ovate to broadly rounded, sessile; flowers white .... *E. rotundifolium* L., roundleaf eupatorium (page 101)
    4. Blades triangular, veiny, on petioles ⅓ to ½ blade length; flowers blue[1] .... *E. coelestinum* L. *(Conoclinium coelestinum* (L.) DC.)[2], mist-flower
5. Blades attached directly to stem; no obvious leaf stalk (petiole) 6
5. Blades with conspicuous petioles 10
    6. Leaf bases of opposite pair of leaves joining around stem .... *E. perfoliatum* L., boneset
    6. Leaves merely sessile or essentially so 7
7. Blade margins toothed on upper half only .... *E. semiserratum* DC., smallflower eupatorium
7. Blade margins toothed below the middle or leaves linear 8
    8. Larger leaves less than ½ inch (1.3 cm) wide 9
    8. Larger leaves more than ½ inch (1.3 cm) wide .... *E. album* L., white eupatorium (page 100)
9. Leaves narrow with reduced axillary branches, appearing whorled .... *E. hyssopifolium* L., hyssopleaf eupatorium (page 100)
9. Leaves without axillary branches, toothed or entire .... *E. leucolepis* (DC.) T. & G., hoarscale eupatorium
    10. Length of typical blade at least 3 times the width .... *E. serotinum* Michx., late eupatorium
    10. Length of typical blade 2 – 2½ times width .... *E. rugosum* Houtt. *(Ageratina altissima* (L.) R. M. King & H. Rob.), white snakeroot (mist-flower fits here also)

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[1] Another blue-flowered eupatorium, ivyleaf eupatorium, *E. ivifolium* L. *(Chromolaena ivifolia* (L.) R. M. King & H. Rob.), is found in southern Louisiana and Mississippi. It is a freely branching, often sprawling plant, with narrow, sessile, sparsely toothed leaves.

[2] Names in parenthesis are indicated as preferred in NLSPN (USDA 1982).

White Eupatorium—*Eupatorium album* L.

White eupatorium, named for the whitish membranous margins of the bracts surrounding the flower heads, is common on periodically burned, open, sandy longleaf-slash pine range.

Mature plants are about 2 feet tall and conspicuously hairy. The leaves are opposite, elliptical, coarse toothed, and without petioles. Blades may be up to 5 inches long and 1 inch wide, but they are commonly about 2 inches long and ½ inch wide. Flat-topped inflorescences appear in midsummer, and flowering continues until frost.

Although boneset, *Eupatorium perfoliatum* L., and smallflower eupatorium, *E. semiserratum* DC. (*E. glaucescens* Ell.) resemble white eupatorium slightly, they are usually confined to wetter sites. Other differences are noted in the key. Late eupatorium, *E. serotinum* Michx., is very common on a wide range of sites. Its leaf blades are about as broad as white eupatorium, but leaves are on petioles about 1 inch long. Late eupatorium may be mistaken for white snakeroot (see key).

Cattle occasionally graze the tender spring leaves of white eupatorium, but the coarse, stiff foliage of older growth is unpalatable.

Range: Louisiana to Florida, extending north to Arkansas, Ohio, and New York.

Perennial. **Stems** 20 – 90 cm tall, harshly pubescent; **leaves** simple, opposite, glandular-punctate, elliptic to lanceolate, serrate, sessile, pilose to scabrous or almost glabrous, 3 – 10 cm long, 1 – 3 cm wide; **inflorescence** a corymb 10 – 25 cm broad, ultimate branchlets terminated by a head of three to five tubular flowers; **heads** 8 – 11 mm long; **bracts** imbricate, lanceolate, white-scarious-margined, glandular-punctate, exceeding the corolla; **corolla** white, tubular, glandular-punctate, 3 – 5 mm long; **fruit** an achene, 3 – 5 mm long.

Dogfennel—*Eupatorium capillifolium* (Lam.) Small

Dogfennel and its close relative, yankeeweed, *Eupatorium compositifolium* Walt., invade abandoned fields, disturbed or overgrazed pastures and forests, and roadsides, especially on dry sandy soils. Dogfennel grows in colonies from a thick, woody, underground base. Plants average 4 to 5 feet in height, but on moist fertile sites they may reach 9 feet. On dry sandy soils, yankeeweed is usually the more abundant of the two.

Dogfennel leaves are deeply dissected into fine, hairlike lobes that give the foliage a needlelike appearance and soft feel. Yankeeweed leaves are also divided, but segments are broader.

The dogfennel inflorescence is a long, conical panicle, usually somewhat lax or nodding. Only yankeeweed has a similar inflorescence, and it is erect. Other eupatoriums are flat-topped. Dogfennel and yankeeweed flower in the fall, later than most associated plants. They emit a pleasing fragrance when in full bloom.

Dogfennel is scarce on forest range in good condition. It has no value as forage or wildlife food. Cattle graze it sparingly, if at all, even where other herbage is scarce.

Range: Texas to Florida, extending north to Tennessee and New Jersey.

Perennial. **Stems** several, from a stout woody caudex, 1 – 3 m tall, pubescent or puberulent, upper stem lax, nodding; **leaves** pinnately dissected into filiform divisions, 2 – 10 cm long, glabrous, glandular-punctate, often with axillary fascicles; **inflorescence** a lax, elongate, conical panicle; **heads** 3- to 5-flowered, 3 – 5 mm long; **flowers** 2 – 3 mm long, corolla white, tubular; **achene** about 1 mm long, smooth.

Hyssopleaf Eupatorium—*Eupatorium hyssopifolium* L.

This eupatorium grows on drainageways and poorly drained flats throughout the longleaf-slash pine type. Although rarely abundant, plants are conspicuous when flowering in late summer.

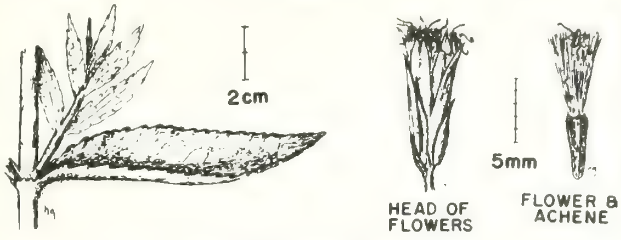
Mature plants may reach 3 feet in height, but average about 2 feet. Primary leaves are about 1½ inches long and ½ inch or less in width. Their sparsely toothed or entire margins frequently roll inward along the lower surface; thus, blades may appear threadlike, resembling those of dogfennel. Hyssopleaf eupatorium is distinguishable by the reduced leafy branches arising from leaf axils. These branches cause leaves, which are generally paired and opposite, to appear numerous and whorled. In some specimens, however, three or four leaves may occur at each node.

Leaves of hoarscale eupatorium, *Eupatorium leucolepis* (DC.) T. & G., are narrow, like those of hyssopleaf eupatorium, and the two species inhabit similar sites. But because hoarscale eupatorium is without branches in the leaf axils, its leaves are distinctly opposite.

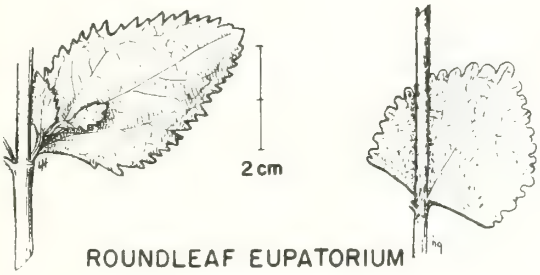
Cattle rarely graze either eupatorium.

Range: Texas to Florida, extending north to Rhode Island.

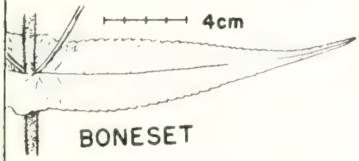
Perennial. **Stems** 30 – 100 cm tall, puberulent or strigose; **leaves** simple, linear, 1 – 10 mm wide, 2 – 6 cm long, opposite or sometimes three to four verticillate, appearing whorled because of axillary leafy branches, upper leaves often alternate, margins entire or few-toothed; **inflorescence** a corymb, 8 – 20 cm wide; **heads** 6 – 9 mm long; **bracts** 4 – 7 mm long, canescent-pilose, scarious-margined; **corolla** white, 3 – 4 mm long; **achene** about 2 mm long, ribbed.



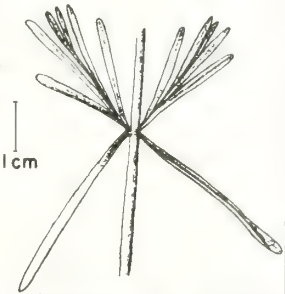
WHITE EUPATORIUM



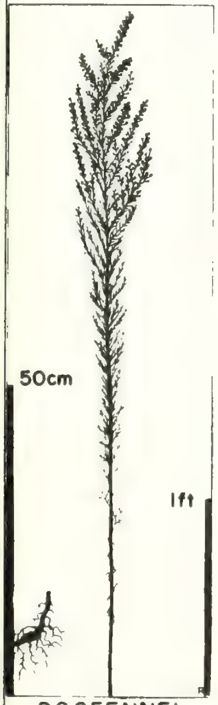
ROUNDLEAF EUPATORIUM



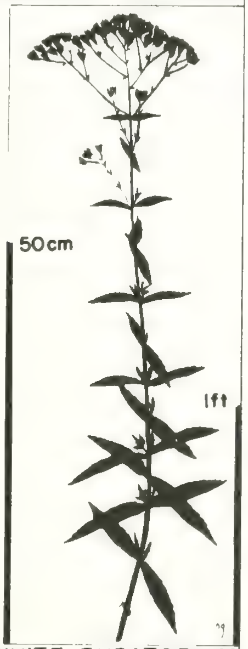
BONESET



HYSSOPLEAF EUPATORIUM



DOGFENNEL



WHITE EUPATORIUM

Roundleaf Eupatorium—*Eupatorium rotundifolium* L.

Roundleaf eupatorium is common on poorly drained uplands. It grows as scattered individuals about 2 feet tall. Leaves are ovate with regular, blunt teeth. Leaf blades, attached directly to the stem, are 1 to 2 inches long and about the same in width.

Roundleaf is the most common eupatorium with leaves about as broad as long. In this treatment it includes those plants with typical ovate leaves and truncate bases *(Eupatorium rotundifolium* L. var. *rotundifolium* of some authors) and also those with wedge-shaped bases *(E. rotundifolium* var. *ovatum* (Bigel.) Torr. or *E. pubescens* Muhl. of some authors).

Eupatorium pilosum Walt. is listed in some books as *E. rotundifolium* var. *saundersii* (Porter) Cronq. It is common on a variety of sites throughout the Coastal Plain from southeastern Louisiana to New York. Leaf blades are generally longer than broad, coarsely and irregularly toothed, and without petioles.

Range: Texas to Florida, extending north to Tennessee and New York.

Perennial. **Stems** 30 – 120 cm tall, tomentulose; **leaves** simple, opposite, sessile, ovate to subrotund, crenate or crenate-dentate, with straight, entire, subtruncate, cordate to broadly cuneate bases, scabrous above, pilose and rugose-veiny beneath, 2 – 7 cm long, width approximately equaling length; **corymb** 10 – 20 cm wide; **heads** 5 – 7 mm long, inner bracts pilose, white-scarious-margined, 3 – 5 mm long; **corolla** white, tubular; **achene** 2 – 3 mm long.

Fragrant Cudweed—*Gnaphalium obtusifolium* L.

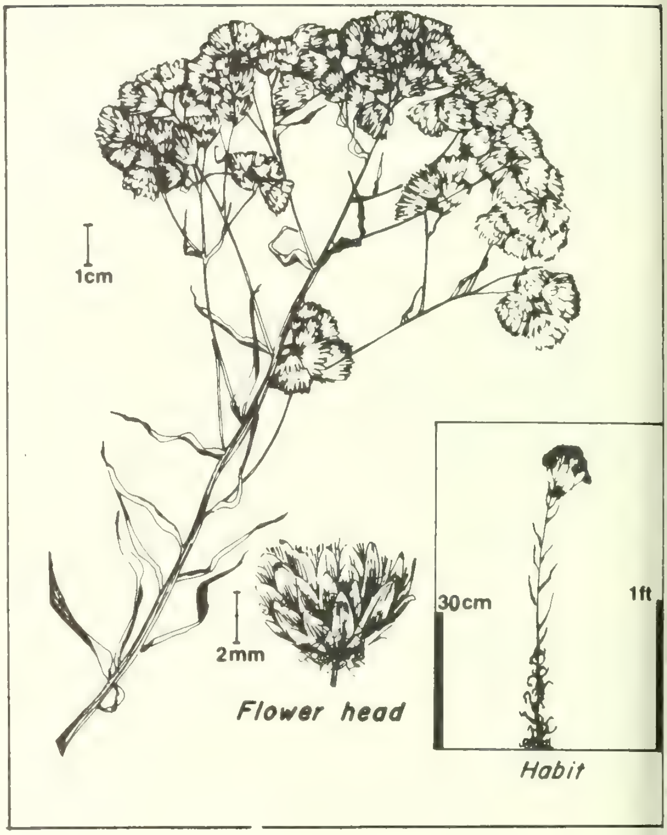
This annual or biennial weed is better known across the South as rabbit-tobacco. It is found throughout the eastern half of the nation but is especially common on the sandy Coastal Plains soils of the South. Other names are catfoot, sweet-everlasting, and old-field-balsam. Like most annual composites, it grows best where competition from perennial grasses is light. Common sites include firelines, overgrazed ranges, and burned areas, especially on dry sandy soils under an open pine canopy. Fragrant cudweed usually grows in clusters of unbranched stems 2 to 3 feet tall. Leaves are lance-shaped, commonly about 3 inches long and ⅛ inch wide. Upper leaf surfaces are green and almost hairless; stems and lower leaf surfaces are woolly with grayish hair. A showy, branched inflorescence terminates each stalk. Flowers are in clusters of constricted, white woolly heads, each about ¼ inch high and opening to about as wide at maturity. Like flowers of the pussytoes, *Antennaria* spp., they lack the conspicuous rays typical of showier composites such as the sunflowers, *Helianthus* spp.

A closely related annual species, *Gnaphalium helleri* Britt., considered a variety of *G. obtusifolium* by Fernald (1950), has glandular-hairy stems that are green in color. The two species are often found growing on the same site.

A common relative of fragrant cudweed is purple cudweed, *Gamochaeta purpurea* (L.) Cabrera, *(Gnaphalium purpureum* L.), a much smaller annual with blunt leaves broadest above the middle. Flower heads sometimes turn purplish at maturity. Like fragrant cudweed, it is found most often on dry, disturbed sites but is frequently found on undisturbed sites. A basal rosette of leaves is formed in late winter and provides some early feed for deer and turkey. Neither fragrant nor purple cudweed is desirable forage for cattle. Purple cudweed occurs in several forms throughout the South; these forms are considered varieties by some authors and separate species by others.

Range: Texas to Florida, extending north to Canada.

Annual or biennial. **Stems** 20 – 150 cm tall, unbranched except in inflorescence; **leaves** alternate, elliptic-linear-lanceolate, 2 – 10 cm long, 2 – 10 mm wide, upper surface green and glabrate to papillate, lower surface gray-woolly; **inflorescence** corymbose; **involucres** in loose clusters at tips of corymb branches, 6 – 7 mm high; **phyllaries** whitish and scarious, in three to five different lengths, pilose on lower half, outer with rounded tips, inner acute, equaling or exceeding flowers; **flowers** all tubular, outer pistillate, inner perfect; **achenes** flat and glabrous.



Bitter Sneezeweed—*Helenium amarum* (Raf.) Rock

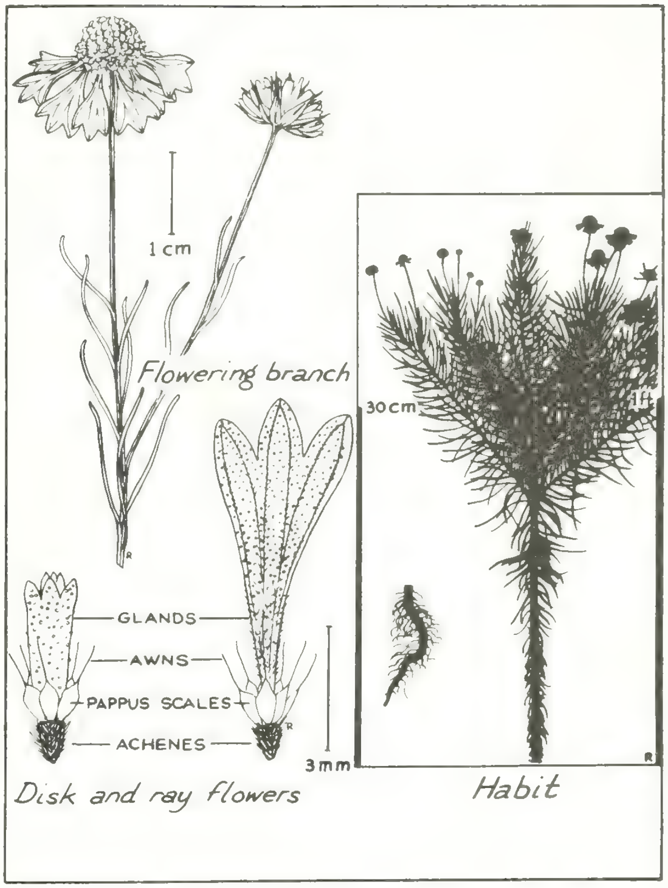
Bitter sneezeweed, like most annuals, is a prolific seeder. It aggressively invades denuded areas, appearing prominently along roadsides, in old fields, and on overgrazed grasslands. It tolerates all but very wet or heavily shaded sites.

Height rarely exceeds 2 feet. Stems vary from simple to profusely branched. Leaves are numerous, threadlike, and up to 3 inches long. Each stem or branch produces many flower heads, which average about an inch in diameter. Collectively, these form a flat-topped cluster. The central disk of the head, consisting of tubular flowers, is surrounded by drooping, three-lobed, yellow ray flowers. Flowering begins in the spring and continues through the growing season.

Bitter sneezeweed is low in palatability. Although it is reportedly toxic to livestock, cattle rarely consume enough to develop serious symptoms. When grazed by dairy cows, a bitter taste is transmitted to the milk.

Purplehead sneezeweed, *Helenium flexuosum* Raf. *(H. nudiflorum* Nutt.), with broader leaves and winged stems, has flower heads resembling those of bitter sneezeweed; disks are purple and rays may be yellow or purplish. Common sneezeweed, *H. autumnale* L., is similar to purplehead except that the central disk is yellow.

Range: Texas to Florida, extending north to Kansas, Missouri, Illinois, and Virginia.



Annual. **Stems** 20 – 50 cm tall, very leafy, simple to corymbosely branched above the middle; **leaves** 1 – 8 cm long, alternate, 1 – 2 mm broad, filiform to linear, densely glandular-punctate, glabrous; **heads** several to numerous, 1.5 – 2.5 cm broad, radiate, solitary on slender, naked peduncles, disk ocher yellow, globular, 6 – 12 mm broad; **disk flowers** 4 – 5 mm long, on a globular, naked receptacle; **ray flowers** 5 – 10, pistillate; **ligules** cadmium yellow, 3-toothed, 5 – 12 mm long, spreading to reflexed, glandular on the back; **achenes** about 1 mm long, brown, hairy; **pappus** scales hyaline, with an awn as long as the body.

Swamp Sunflower—*Helianthus angustifolius* L.

Its name is misleading, for swamp sunflower is the most common of the perennial forbs on a variety of upland range sites, including dry sandy ridges. It occurs also on low, open flatwoods and other wet sites.

Like most sunflowers, stems and leaves are rough to the touch. In dense grass, stems seldom exceed 2 or 3 feet in height, the plants usually being inconspicuous until the flower heads appear. On firelines or other clearings, this species may grow more than 6 feet tall. The lower stem is covered with short, stiff hairs.

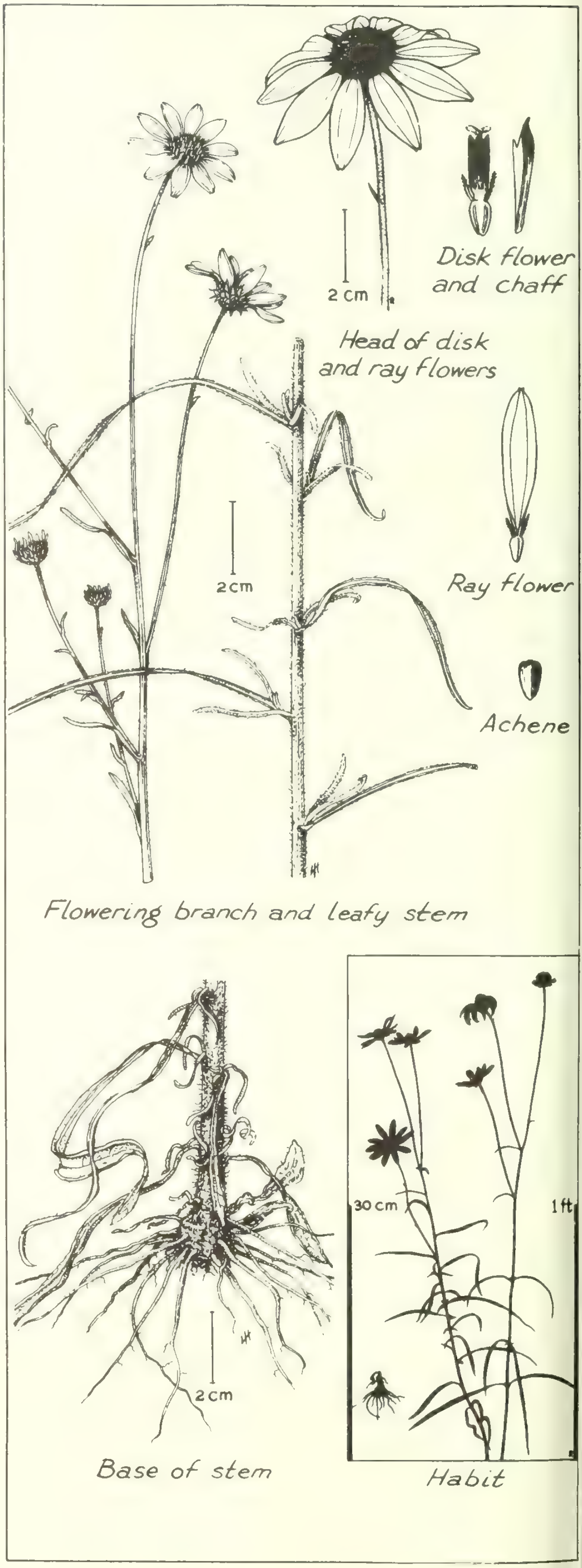
On open sites the leaves average 2½ inches long and less than ⅛ inch wide. They appear even narrower because their margins roll under. Under timber, leaves may be flat and up to ¾ inch wide. Heads, 1½ to 2 inches broad, appear by early October. Each has a purplish central disk about ½ inch in diameter and an outer ring of yellow ray flowers. Leaves, though slender, are almost fleshy. They are covered throughout with short, stiff hairs that project from small conical bases.

Although early growth of Texas ironweed resembles swamp sunflower, it is easily distinguished when its flower heads appear in early summer. Its inward-rolled leaves are strongly lance shaped; those of swamp sunflower are almost linear. Swamp sunflower intergrades with *Helianthus floridanus* Gray ex Chapm. in south Georgia and east Florida to produce plants with flowers having yellow disks (Godfrey and Wooten 1981).

Swamp sunflower is the most valuable forage forb on longleaf-slash pine-bluestem range. It is high in protein, often containing more than 10 percent in the full-leaf stage. Cattle eat it throughout the growing season. Grazing causes plants to branch freely. Site preparation, such as disking for direct seeding, causes swamp sunflower to increase. Deer eat the leaves and young stems, and the seeds provide food for quail and doves.

Range: Texas to Florida and New York, extending inland to Kentucky, Indiana, and Missouri.

Perennial. **Stems** 50 – 150 cm tall, branched above, arising from a short, erect crown; **leaves** 8 – 20 cm long, 0.3 – 1.5 cm wide, simple, sparse to numerous, sessile, alternate (basal sometimes opposite), attenuate, the margins revolute in the very narrow leaves; **heads** many, radiate, 3 – 7 cm broad, **involucral bracts** 8 – 12 mm long, subulate; **disks** dark purple, 10 – 15 mm long, fertile; **chaff** about 7 mm long, red-violet tipped, 3-toothed; **rays** 10 to 13, neuter, bright yellow orange, 1 – 3 cm long, 5 – 6 mm broad; **achenes** 3 – 4 mm long, flattened, dull black, mottled with tan; **pappus** of two caducous scales.



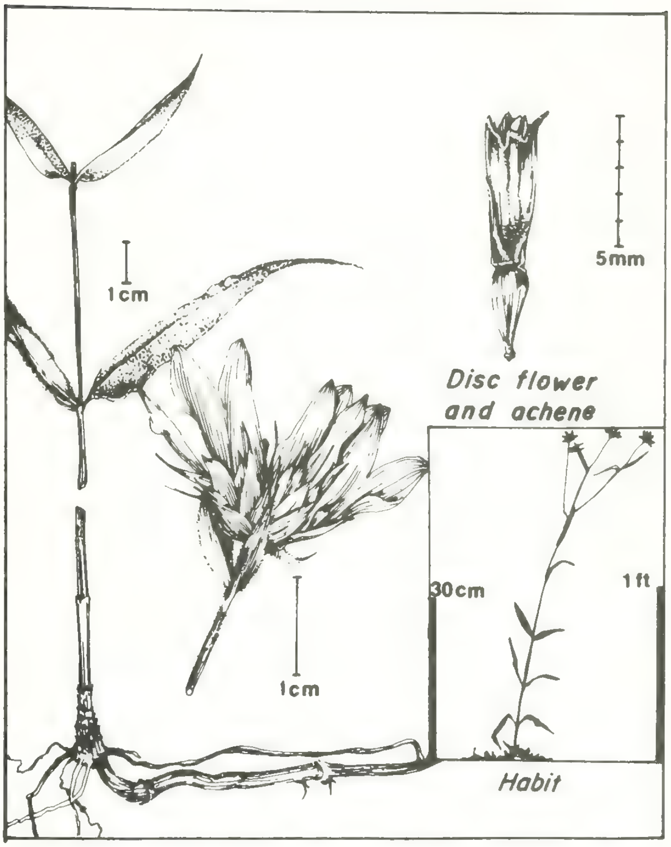
Hairy Sunflower—*Helianthus hirsutus* Raf.

Hairy sunflower is common across the South but is not as abundant as swamp sunflower. It occurs on sandy sites and seems to be fairly shade tolerant.

Plants are 2 to 4 feet tall, branching from the axils of the upper leaves. A single flowerhead, about 2 inches in diameter, terminates the main stem and lateral branches. Disk flowers as well as rays are yellow. Leaves are lance shaped and opposite, although uppermost leaves may be alternate. Usually gray green in color, leaves may be ¼ to ½ inch wide and up to 7 inches long. As in many sunflowers, short, stiff, glandular hairs make leaves and stems rough to the touch. Stem hairs, however, may be longer and softer than those of the leaves.

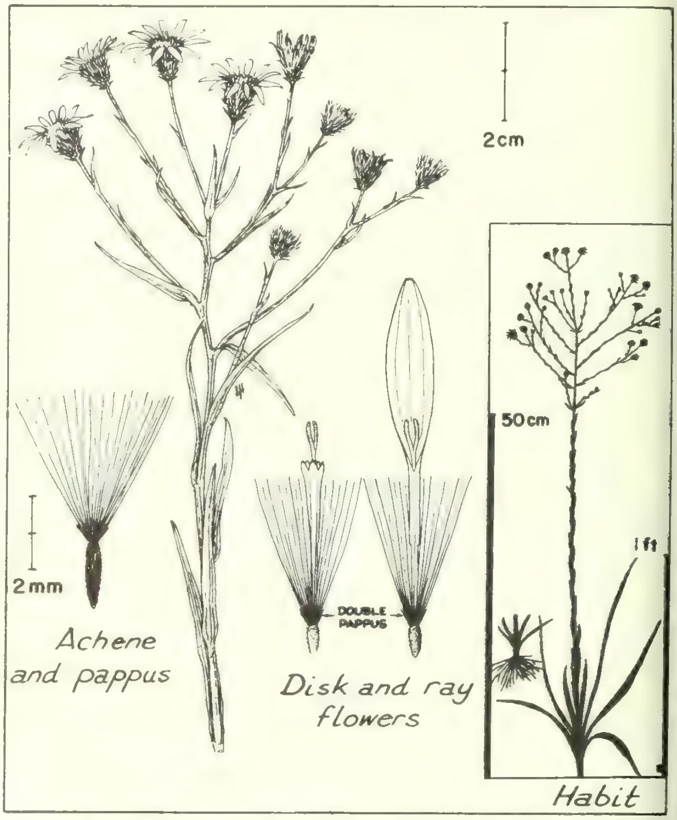
Cattle eat the immature foliage, but on forested range, plants are seldom abundant enough to provide a significant amount of forage. It is not recognized as a valuable livestock or wildlife food plant.

Range: East Texas, Oklahoma, and Arkansas to Georgia, extending north to Minnesota and Pennsylvania.



Perennial. **Stems** erect, from stout rhizomes, 50 to 170 cm tall, internodes hirsute or scabrous; **leaves** opposite (uppermost may be alternate), sessile or on petioles up to 15 mm long, blades ovate to lanceolate, up to 7 cm broad and 18 cm long, lower surface hirsute or scabrous; **flower heads** solitary at ends of main stem and lateral branches; **disk** 1 – 2 cm broad, flowers yellow; **rays** yellow, 15 – 35 mm long; **involucral bracts** lancolate, long-tapering, exceeding the disk; **achene** about 4 mm long, winged.

Grassleaf Goldaster—*Heterotheca graminifolia* (Michx.) Shinners—*(Chrysopsis graminifolia* (Michx.) Ell.)



Grassleaf goldaster grows on a variety of sites but is most common on sandy soils. Until the inflorescences appear in summer, the plants superficially resemble grasses. The elongate leaves measure up to 10 inches and have prominent longitudinal veins. Long silky hairs paralleling the veins lie flat against the leaf; they produce a silvery sheen, which the dead leaves retain through the winter.

Plants, including the profusely branched inflorescence, grow to 3 feet tall. The asterlike flower heads are about ⅝ inch in diameter, with golden-yellow ray flowers. Several rows of overlapping, narrow bracts enclose the bases.

Soft goldaster, *Heterotheca pilosa* (Nutt.) Shinners, is a common taprooted annual on sandy sites from Texas and Mississippi to Kansas and Missouri. It occurs less commonly in Tennessee and North Carolina. Flower heads are similar to those of grassleaf goldaster, but larger. Foliage of soft goldaster lacks the silky hairs and parallel venation of grassleaf. Lower stem leaves are toothed and semi-clasping. Leaves on branches are reduced in size, and entire. Leaves and stems have spreading white hairs of varying length and density. Like most annual forbs, soft goldaster is most abundant on roadsides, firelines, and other disturbed sites.

Maryland goldaster, *H. mariana* (L.) Shinners, a perennial with long, cobwebby hairs on stems and leaves of young growth, resembles soft goldaster and grows on the same sites. Camphorweed, *H. subaxillaris* (Lam.) Britt. & Rusby, is a weedy, almost woody, goldaster with rough, coarsely toothed leaves, that may grow unbranched to a height of 8 feet or may form bushy branched plants about 3 feet tall.

Because of its scattered distribution, grassleaf goldaster contributes only a small part of the cattle diet. Nutritive value exceeds that of most grasses but palatability is only fair. Cattle graze it mainly in the spring when plants are young and succulent.

Range: Louisiana to Florida and Virginia.

Perennial. **Stems** 30 – 90 cm tall; **basal leaves** 10 – 30 cm long, 0.2 – 1.0 cm broad, veins parallel; **cauline leaves** appressed, alternate, decreasing in size up the stem; **inflorescence** irregularly corymbose; **heads** turbinate, yellow, radiate, solitary at the ends of elongate ascending peduncles; **involucres** 7 – 11 mm high; **phyllaries** in several series, loosely white-hairy to glandular; **disk flowers** 7 – 8 mm long, numerous, fertile; **ray flowers** fertile, the narrow ligule 8 – 12 mm long; **pappus** double; **achene** about 3 mm long, linear, dark brown, hairy.

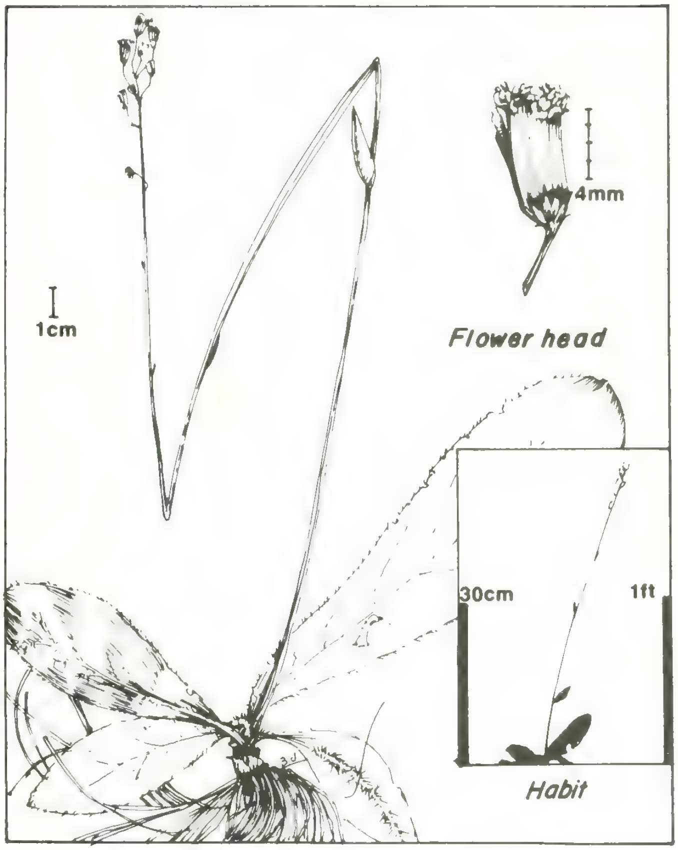
Hawkweed—*Hieracium gronovii* L.

This southern species represents a group of native hawkweeds whose primary ranges are mainly in the northern or mountainous parts of the United States. Numerous species are introduced weeds from Europe. *Hieracium gronovii* has hairy stems and oblanceolate basal leaves up to 7 inches long. Flower stalks are 2 to 3 feet tall, with several reduced leaves, and are terminated by an erect panicle of flower heads. Flower heads are about ¼ inch long with no disk flowers. The yellow ray flowers are barely visible behind the almost tubular outer ring of greenish bracts. *H. gronovii* occurs most frequently in open sandy woodlands, although it is seldom found on burned and grazed range. It is a common weed of roadsides and lawns.

Other species of *Hieracium* that range into the South occur in the Piedmont and adjacent areas of the Coastal Plain. Western species are found in Arkansas and Missouri. Several are common weeds of pastures. Most have yellow flowers and hairy stems and leaves, and all have milky sap.

Hawkweed is a palatable forage plant for livestock, and deer eat flower heads and stem tips in summer. It is seldom abundant enough, however, to be considered a valuable forage component of the range.

Range: Texas to Florida, extending north to Michigan and Massachusetts.



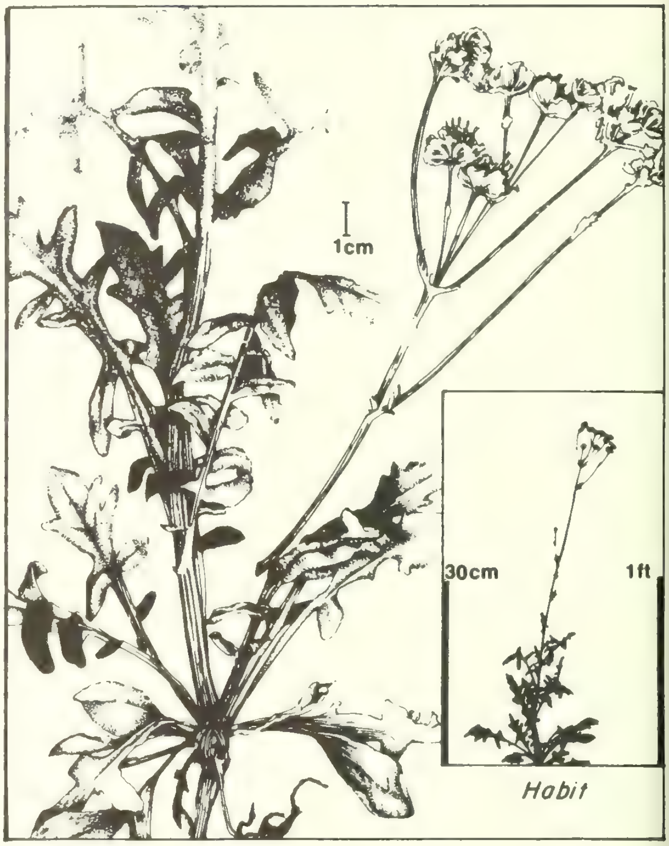
Perennial. **Stems** erect, to 1 m tall, pilose to pubescent; **leaves** mostly basal, oblanceolate to elliptic, 8 – 17 cm long, to 5 cm wide, abruptly reduced up the stem, pilose; **inflorescence** a narrow, erect panicle; **involucres** 6 – 8 mm long, bracts acute to acuminate, **heads** 20- to 40-flowered, all ray flowers; **rays** yellow; **nutlets** fusiform, 3 – 4 mm long; **pappus** tan.

Ragweed Woollywhite—*Hymenopappus artemisiifolius* DC.

Ragweed woollywhite is conspicuous from April through June on roadsides through sandy open woodlands of east Texas and southwestern Louisiana. It is a biennial, about 3 feet tall when mature, with a basal rosette of leaves and a thick taproot. Basal leaves are entire or once-divided, green on the upper surface and "woolly-white" below; stem leaves are deeply lobed and reduced in size up the stem. Flower heads are in axillary and terminal clusters in a stiffy branched inflorescence. Membranaceous bracts enclosing the flower heads are whitish, often tinged with red or purple. Another species, flattop woollywhite, *Hymenopappus scabiosaeus* L'Her., grows southwide on dry sandy or clayey soils. Leaves of flattop woollywhite are more finely divided than those of ragweed woollywhite, and flowers are completely white.

Basal leaves of ragweed woollywhite are eaten by cattle and deer in early spring when other green forage is scarce. Flowers appear by the first of May and mature plants are not grazed under moderate utilization.

Range: Texas and Louisiana.

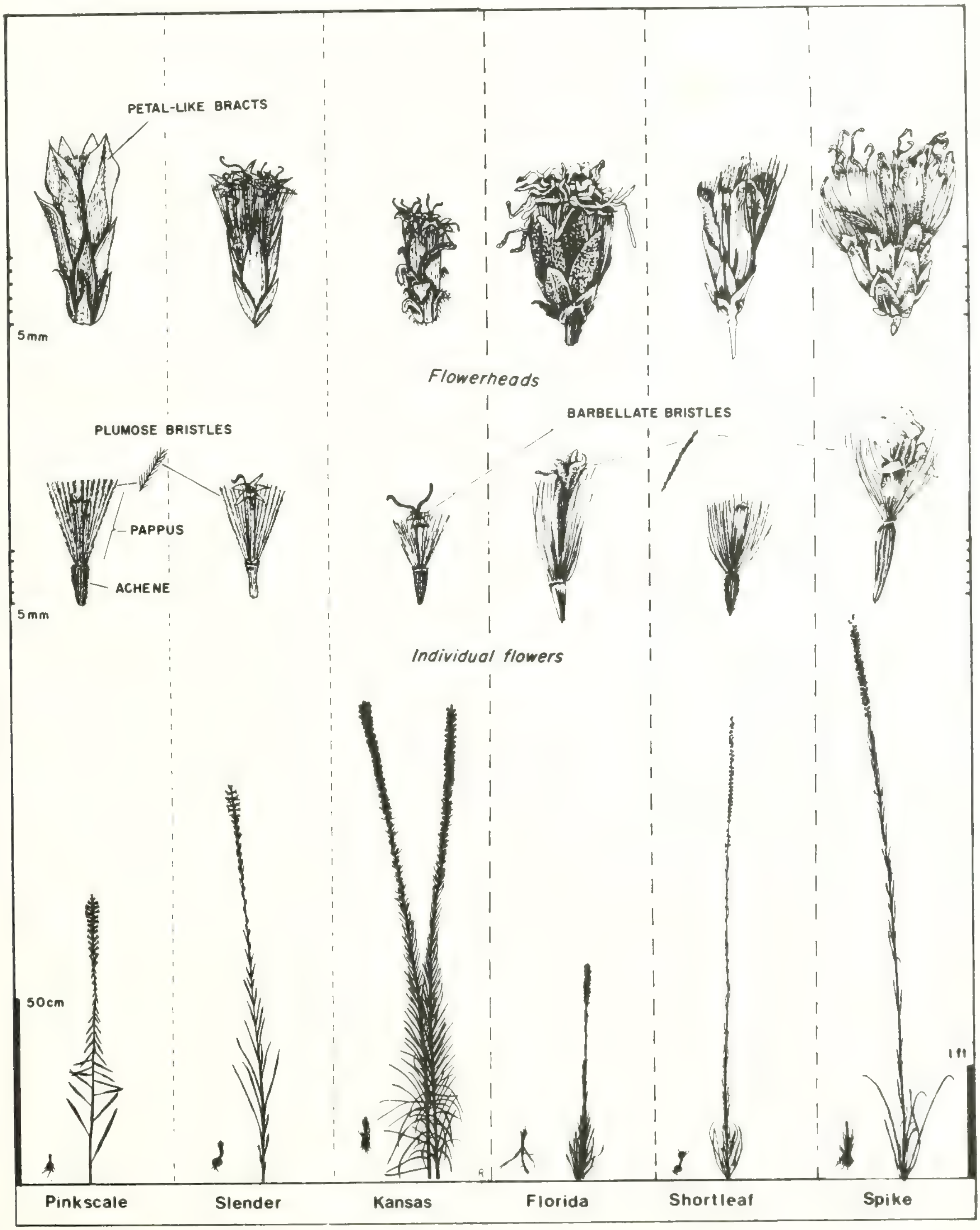


Biennial. **Stems** to 90 cm tall; **leaves** of basal rosette 8 to 18 cm long, entire or pinnatifid, upper leaves reduced and pinnatifid; **inflorescence** cymose, involucres campanulate, about 15 mm wide; **phyllaries** white or tinged with red, heads with disk flowers only; **corollas** funnel shaped, rose colored, 3.5 – 5 mm long; **pappus** of 16 – 18 scales about 1 mm long; **achenes** 4-sided, 3 – 4 mm long.

Gayfeathers—*Liatris* spp.

About 20 gayfeathers, or blazing-stars, are found in southern pine forests. Several are found southwide, while others have limited distributions. Most are showy, slender, erect, narrow-leaved perennials, with stems arising from a bulblike base. Leaves are generally longest at the base of the plant and decrease in length up the stem. The basal leaves form a rosette in the spring before stalks begin growth.

The gayfeathers inhabit open to moderately timbered sites. Most grow best on sandy soils, although some require fairly wet sites. Cattle may eat new growth but generally reject older herbage. Gayfeathers are moderately resistant to grazing, but disappear on heavily used areas. Thus, an abundance of gayfeathers indicates that the range is not being overgrazed.



Slender Gayfeather—*Liatris acidota* Engelm. & Gray

Slender gayfeather grows on moist, well-drained soils of the Coastal Plain in Louisiana and east Texas. Plants are usually most abundant on sandy ridges and on pimple mounds in areas that are otherwise wet.

Stems grow about 2 feet tall from bulblike corms. Leaves are gray-green and hairless, 1/16 to 1/8 inch wide. Lower leaves are up to 8 inches long, but at about 6 inches above the ground, leaf length abruptly diminishes to about 1 inch. The uppermost leaves are even shorter—less than 1/4 inch long.

Flower heads, averaging 1/2 inch long and short stalked, are spaced about 1/4 inch apart. Rose-purple flowers, two to four per head, are surrounded by a loose whorl of stiff, sharp-pointed bracts. The bracts are green at first, turning dark purple at flowering. They vary in length, but the longest are shorter than the flowers. The inflorescence comprises about 1/3 of the plant height. Heads at the summit begin maturing in midsummer; flowering continues downward, with the lowermost heads maturing last.

Young plants are occasionally grazed by cattle, but older herbage is rejected unless better forage is scarce.

A similar but taller species, shortleaf gayfeather, *Liatris tenuifolia* Nutt., is common on dry sandhills from Florida to South Carolina. Average height is 3 to 4 feet, but plants up to 6 feet tall are common. Stems of the tallest plants measure only about 1/8 inch in diameter near ground level.

Range: Coastal Plain of Texas and Louisiana.

Perennial. **Stems** glabrous, 30 – 70 cm tall, from corms; **leaves** linear, alternate, the lower 1 – 3 mm wide, 10 – 18 cm long, the upper less than 1 mm wide and 2 cm long, ascending, glabrous but obscurely white-scurfy; **inflorescence** slender, spikelike, 10 – 25 cm long; **heads** sparse, about 1 cm long, 3- to 5-flowered; **bracts** of mature flowers few, the inner 6 – 7 mm long, purple, stiff, acuminate, not scarious-margined nor petaloid; **flowers**, including the mature achene, about 10 mm long, exceeding the bracts; **corolla** equaling the plumose **pappus**, rose-magenta.

Pinkscale Gayfeather—*Liatris elegans* (Walt.) Michx.

This gayfeather usually grows 2 to 3 feet tall. It flowers in late summer or fall, and the pink or rose-colored floral bracts provide color long after flowers have withered.

Lower leaves are generally less than 6 inches long and up to 3/8 inch wide. Leaf size gradually diminishes up the stalk. The upper leaves point downward at about 45°.

The inflorescence is 4 to 6 inches long and about 1 inch in diameter. Sometimes, however, stalks of the lower heads elongate, producing a cone-shaped inflorescence. Color is provided mostly by the floral bracts, which extend beyond the flowers, obscuring the petals. These colorful bracts and the downward pointing leaves are reliable distinguishing characteristics of pinkscale gayfeather. The inflorescence is less densely flowered than that of Kansas gayfeather, but denser than in slender gayfeather. Floral bracts (except the tips) and stems are loosely coated with short, stiff, white hairs.

Although cattle may occasionally graze young growth, pinkscale gayfeather is not a valuable forage plant. Deer eat the foliage in spring and summer.

Range: Texas and Oklahoma to Florida and South Carolina.

Perennial. **Stems** 30 – 100 cm tall, pubescent, leafy, unbranched, from corm; **leaves** linear-spatulate to lanceolate, alternate, sessile, punctate, acute; **basal leaves** ascending, to 12 cm long and 7 mm wide; **upper leaves** decurrent, diminishing in length to 1 cm among the heads; **inflorescence** 10 – 40 cm long, 3 – 6 cm broad, cylindrical, spikelike, with many elongate sessile heads, or pedicellate heads on short, branched peduncles; **heads** slender, 1.5 – 2.5 cm long; **tubular flowers**, white to lavender, three to five per head, 9 – 11 mm long; **involucral bracts** in several series, the outer green, punctate, pubescent, various lengths, the inner 10 – 18 mm long, 2 – 3 mm wide, green, punctate and pubescent below, with rose-magenta t white, serrulate, petaloid tips; **achenes** 4 – 6 mm long cylindrical, pointed, ribbed, pubescent; **pappus** long plumose, 9 – 11 mm long.

Florida Gayfeather—*Liatris garberi* A. Gray

Florida gayfeather, a slender, erect perennial 6 t 24 inches tall, occurs only in peninsular Florida. It i most common on open to moderately stocked pin stands or sandy flatwoods soils in the pine-wiregras type. It is similar to other gayfeathers in its rose-pur ple spike of flowers but is unique in having flesh roots rather than a bulblike base found in most othe gayfeathers.

Cattle graze new growth in spring and early sum mer and deer eat the leaves. Like other gayfeathers, is not abundant enough to be considered a valuabl forage plant.

Range: Central and southern peninsular Florida.

Perennial. **Stems** erect, 20 – 50 cm tall, hirsute; **leav** linear, at base of plant 10 – 30 cm long, abrupt reduced upward, those of upper stalk less than 1 c long, ascending; **inflorescence** a spicate raceme; **heads** 10 – 12 mm long, 8- to 10-flowered, **involucral** bracts broadly elliptic, ciliate, and mucronate; **corolla** rose purple, tube 6 – 8 mm long, glandular-punctate; **pappus** tan, bristles barbellate, as long as the corolla tube; **achene** 2 – 3 mm long, ribbed, pubescent.

Kansas Gayfeather—*Liatris pycnostachya* Michx.

This large gayfeather is found only in the western end of the southern pine belt, on the edge of its preferred prairie habitat. Plants may reach 5 feet in height, growing mainly on well-drained sandy soils in forest openings. A striking plant, it is planted as an ornamental in the northeastern states.

Plants are hairy throughout. Lower leaves, up to a foot long and ⅜ inch wide, generally droop. Leaf size gradually diminishes up the stem, the smaller upper leaves pointing stiffly skyward.

The dense, spikelike inflorescences are 6 inches to a foot long. Heads are about ⅜ inch long, with 5 to 12 flowers per head. Floral bracts are numerous; their tips, which curl away from the head, are purple tinged.

Cattle graze Kansas gayfeather sparingly. Deer eat spring and summer foliage.

Range: Texas and Louisiana to South Dakota and Indiana.

Perennial. **Stems** several, 60 – 120 cm tall, stiff, hirsute, from corm; **leaves** 10 – 30 cm long, alternate, 4 – 10 mm wide below, mostly ascending, much reduced above, pubescent, punctate; **inflorescence** 15 – 30 cm long, about 2 cm wide, cylindrical, spikelike; **heads** 5- to 12-flowered, about 1 cm long, cylindrical, sessile; **flowers** 10 – 11 mm long, rose magenta; **involucral** bracts in several series, green or purplish, pubescent, lanceolate-acuminate, the acute tips squarrose, reflexed or spreading; **achene** 4 – 6 mm long, ribbed, pubescent; **pappus** with barbellate bristles.

Spike Gayfeather—*Liatris spicata* (L.) Willd. var. *spicata*

This gayfeather is common on moist or marshy sites throughout most of the eastern United States. It extends into the mountains of West Virginia and Tennessee. As the name indicates, flowers are in a fairly dense spike terminating a stalk 2 to 6 feet tall. Stems of the largest plants may be ¼ inch in diameter.

As with other gayfeathers, the main value of this plant is in the beauty of its spike of lavender flowers. Early leaves and immature flower stalks may be grazed by livestock or deer, but after flowers form, plants are not eaten.

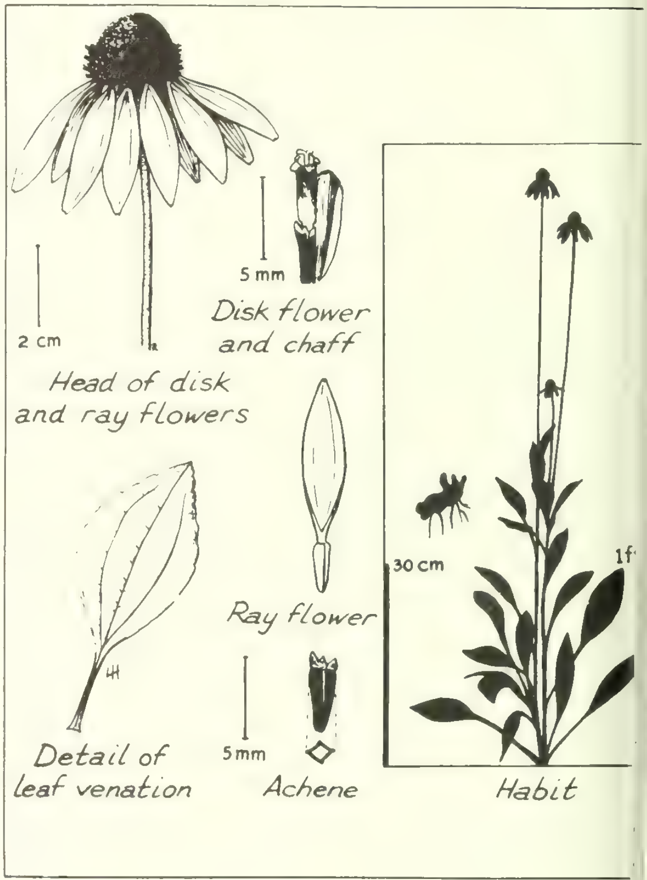
Although most gayfeathers are superficially similar, spike gayfeather can usually be distinguished by its large size and hairless stems and leaves. Rootstocks are round in young plants but develop into elongated taprootlike masses in older plants that can be separated for vegetative propagation. Basal leaves are long and narrow, and remnants form a fibrous tuft at the base of mature plants.

Typical spike gayfeather, with thick stems and dense spikes, is found in the northern portion of the range and around bays and lakes in the southern Appalachians; the more slender variety, *Liatris spicata* var. *resinosa* (Nutt.) Gaiser, with a loosely spicate inflorescence, is most common on Coastal Plains pinelands.

Range: East of the Mississippi River, from the Gulf of Mexico to Ontario and New York.

Perennial. **Stems** stiffly erect to 2 m tall, from a thick round or elongated rootstock, glabrous or rarely hirsute; **leaves** numerous, linear or linear-lanceolate, basal 10 – 40 cm long, 5 – 20 mm wide, gradually shorter up the stem; **inflorescence** a spike 30 – 70 cm long; **heads** subcylindrical, 4- to 18-flowered, 8 – 15 mm long and 5 – 10 mm thick when flowering, phyllaries appressed, mostly obtuse but sometimes slightly acuminate, with narrow scarious margins turning purplish at flowering; **achene** 4 – 7 mm long; **pappus** 5 – 7 mm long, barbellate, setose.

Rough Coneflower—*Rudbeckia grandiflora* var. *alismatifolia* (T. &. G.) Cronq.



Rough coneflower, or plantainleaf coneflower, as variety *alismatifolia* is also called, is a perennial with thick, fleshy rootstocks, common on well-drained Coastal Plains pinelands west of the Mississippi River. Mature plants are 16 inches to more than 3½ feet in height.

Foliage is useful in identifying the species before flowering. Basal leaves are paddle shaped, resembling leaves of water-plantain *(Alisma* spp.). In large specimens, petioles may reach 10 inches, with blades 5 inches long and 2 inches wide. Leaf size diminishes up the stem. Blade margins are sparingly toothed or wavy. Often the upper half of the plant is leafless.

The name "coneflower" refers to the prominent, cone-shaped central disk of brownish-purple flowers, averaging ¾ inch in diameter. Yellow ray flowers, 10 to 15 per head and an inch or more long, droop from the base of the cone. They fall when the head is mature, leaving the persistent cone and its subtending bracts.

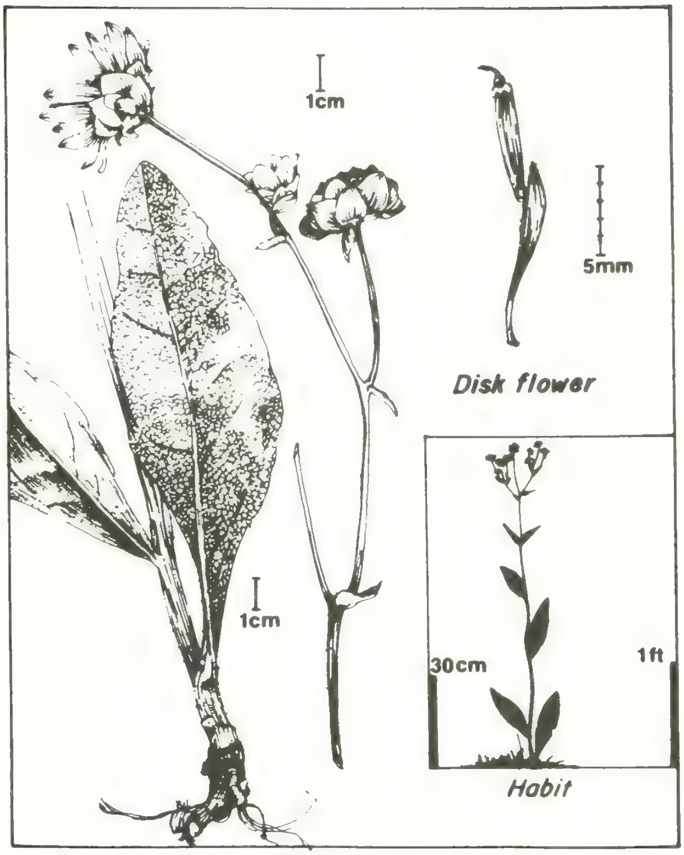
Typical rough coneflower, *Rudbeckia grandiflora* (Sweet) DC. var. *grandiflora*, whose stems and foliage are hairier then those of var. *alismatifolia*, has a more nothern range, although the species is restricted to an area west of the Mississippi River from east Texas and Louisiana to Missouri. A small and highly variable coneflower, common southwide, is black-eyed-susan, *R. hirta* L. It is distinguishable from rough coneflower by its basal leaves, which are usually 2 to 3 inches long and lance shaped.

Pale echinacea, *Echinacea pallida* (Nutt.) Nutt., a close relative of the coneflowers, with pink to purple ray flowers, is common on sandy pinelands of Arkansas and western Louisiana.

Range: East Texas to central Arkansas and Louisiana.

Perennial. **Stems** 50 – 90 cm tall, from a woody rhizome, usually simple, slender, glabrous to slightly scabrous above; **basal leaves** long-petioled, the blade 5 – 12 cm long, 3- to 5-ribbed, scabrous, punctate; **upper leaves** similar, but smaller and sessile, alternate; **heads** 3 – 5 cm broad (rays reflexed), radiate, solitary on elongate, leafless peduncles; **involucral bracts** linear, reflexed, scabrous; **disks** 1.5 – 2 cm broad, dark brownish purple, subglobose; **disk flowers** on a conical, chaffy receptacle, 8 – 9 mm long, fertile, dull purple-black tipped, petals reflexed, stigmas bright yellow; **chaff** 4 – 5 mm long, enclosing the disk flower; **rays** 10 to 15, 3 – 4 cm long, neuter, yellow; **achene** about 5 mm long, 4-angled; **pappus** a crown of uneven, deltoid teeth.

Slender Rosinweed—*Silphium gracile* Gray



The rosinweeds, like the sunflowers, have yellow flower heads and rough leaves and stems. Most have several series of broad greenish bracts at the base of each flower head, making the heads denser than those of most sunflowers and other composites.

Slender rosinweed is found in sandy or gravelly soils of the Gulf Coastal Plain. Flowering plants are from less than 2 feet to over 4 feet tall. Flower heads are about 2 inches broad with ovate bracts. Stems and leaves are rough with bristly hairs. Bracts of the flower heads are hairless except for a fringe of short bristles around the outer margins. Basal and lowest stem leaves are elliptical or lance shaped with definite petioles; upper stem leaves are gradually reduced in length, ovate, and sessile. Lower stem leaves are often opposite and upper leaves are alternate, but leaf arrangement is apparently variable.

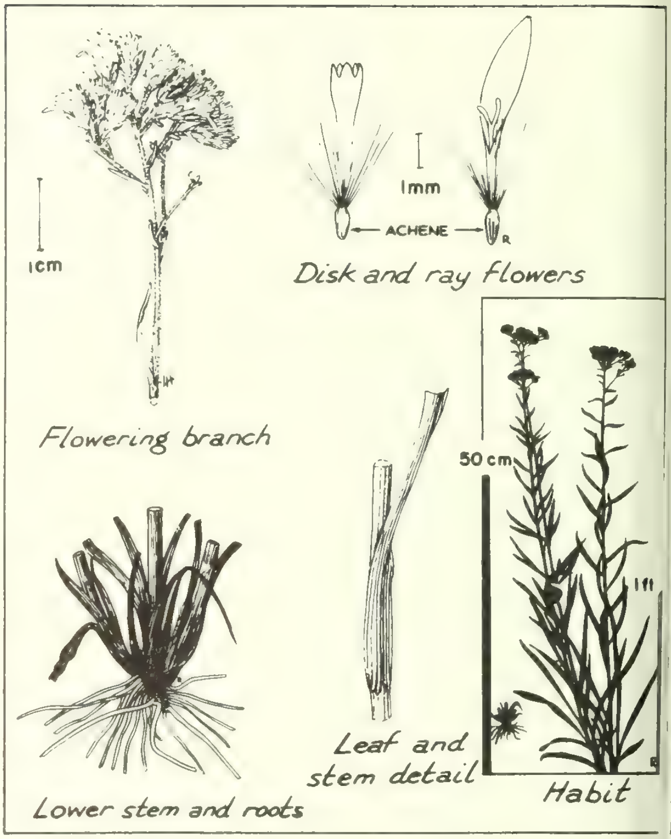
Immature flower stalks of slender rosinweed are eaten by cattle in the spring. Although fairly common on sandy pinelands, it is seldom abundant.

Other rosinweeds common through most of the South include compassplant, *Silphium laciniatum* L., which has deeply pinnately divided basal leaves; wholeleaf rosinweed, *S. integrifolium* Michx., with opposite, entire, stem leaves; and sand rosinweed, *S. asteriscus* L., which has alternate or opposite leaves. *Silphium compositum* ssp. *ovatifolium* (T. & G.) Sween. & T. R. Fisher is common on southeastern sandy pinelands and flatwoods. The large basal leaves have long petioles, are ovate in outline, and may be coarsely serrate or deeply cleft.

Range: Coastal Plain, Texas to Alabama.

Perennial. **Stems** 30 – 90 cm tall from a woody base, scabrous to spreading-pubescent; **leaves** near base petiolate, elliptic-lanceolate, 10 – 30 cm long, 5 – 10 cm wide, entire to remotely dentate-serrate or lacerate; **upper leaves** sessile, gradually reduced up the stem to remotely alternate bracts; **heads** at anthesis 3 – 5 cm wide, solitary and terminal at tip of stalk or at end of few inflorescence branches; **involucral bracts** ovate to orbicular-ovate, glabrous except for ciliate margins; **ray flowers** yellow, fertile, rays 1 – 3 cm long; **disk flowers** dark purple or brown, sterile; **achenes** about 1 cm long, orbicular-oval, broadly winged with notch at apex, glabrous.

Shiny Goldenrod—*Solidago nitida* T. & G.



Shiny goldenrod inhabits dry upland sites, both open and timbered. Stems arise from rootstocks to a height of 2 to 2½ feet. The inflorescence, though yellow flowered and late blooming, is flat-topped rather than conical, making mature plants easy to distinguish from those of most other goldenrods. The alternate leaves are similar in texture and venation to those of fragrant goldenrod but much larger. Lower leaves are 4 to 5 inches long, and occasionally up to 12 inches long. The leaves decrease in size going up the stem, with those subtending the inflorescence only 1 to 2 inches long. Blades are narrowly lance shaped and entire, except for sparse, obscure teeth on the lower leaves. Width ranges from about ⅜ inch in the lower leaves to 1/16 inch in the uppermost. Thin, almost imperceptible hairs coat the upper stem and inflorescence branches; otherwise, plants are hairless.

Flower heads, about ¼ inch long, are much larger than those of most goldenrods. Each flower produces an achene about 1/16 inch long.

Slimhead goldenrod, *Euthamia leptocephala* (T. & G.) Greene (*Solidago leptocephala* T. & G.), is a similar plant found on a variety of sites throughout the Southeast. Like shiny goldenrod, it is practically hairless, with a flat-topped inflorescence and lustrous leaves. Lower leaves are only about half as long as those of shiny goldenrod, and length reduction in upper leaves is less pronounced.

Range: Texas, Oklahoma, and Louisiana.

Perennial. **Stems** 40 – 90 cm tall, smooth and glabrous below inflorescence, striate-ribbed; **leaves** numerous, alternate, entire, or obscurely serrate, coriaceous, glabrous and somewhat lustrous, linear or narrowly linear-elliptic, lower leaves 7 – 30 cm long and 5 – 10 mm wide, gradually reduced going up the stem to 3 – 5 cm long below inflorescences, 1 – 2 cm long in inflorescence branches; **inflorescence** corymbose with finely pubescent branches; **heads** 6 – 8 mm long, narrowly campanulate, 7- to 12-flowered, bracts obtuse, scarious-margined, yellowish; **ray flowers** three to four per head, pistillate, yellow; **disk flowers** perfect, yellowish; **achene** glabrous, 10-ribbed, about 1.5 mm long.

Fragrant Goldenrod—*Solidago odora* Ait.

Fragrant goldenrod is the most common goldenrod on southern pine range. It is named for the spicy, aniselike fragrance of the crushed leaves. This character is not dependable, however, as some plants emit little or no odor.

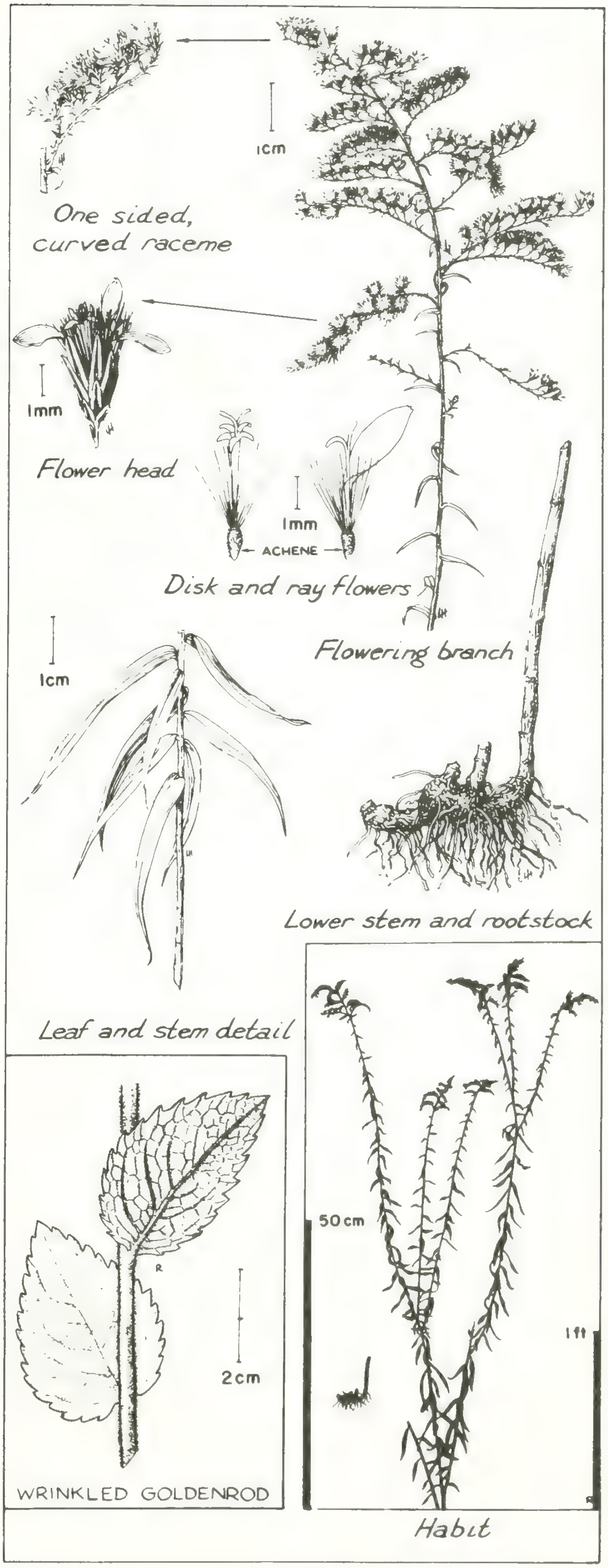
Fragrant goldenrod grows mainly on dry sandy sites, especially in cutover timberlands, pastures, and abandoned fields. Where competition is light, plants may reach a height of 5 feet. In dense grass, height rarely exceeds 2 feet. Stems, arising from thick rootstocks, are hairless and usually reddish brown. The hairless, lance-shaped leaves are up to 4 inches long and ½ inch wide. They generally point downward, and those of the upper stem are greatly reduced. Heads of the golden-yellow flowers are less than ¼ inch long and about 1/16 inch wide.

Although cattle occasionally graze young growth, fragrant goldenrod is not a valuable forage plant. Deer eat the immature inflorescences as well as the young shoots. Goldenrods are best known for the suffering they cause in the fall among persons prone to hay fever.

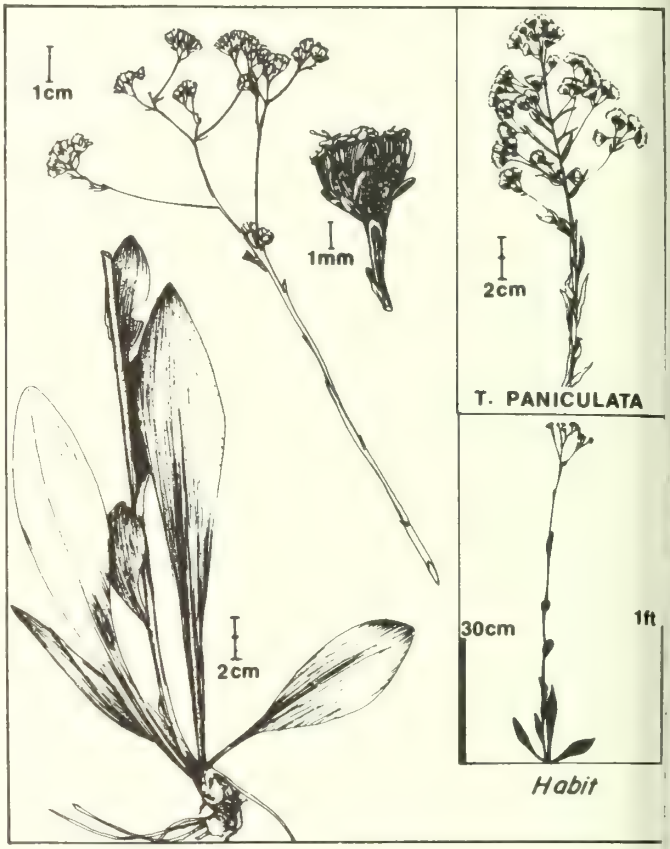
Tall goldenrod, *Solidago altissima* L. (*S. canadensis* var. *scabra* (Muhl.) T. & G.) is a common roadside weed throughout the Gulf Coastal Plain. Also common throughout the South is wrinkled goldenrod, *S. rugosa* Miller. Its inflorescence is very similar to that of fragrant goldenrod, but its leaves are ovate and have prominent veins that lend a wrinkled appearance to the blades. Rough goldenrod, *S. radula* Nutt., occurs on prairies, open rocky plains, and dry woods, especially in calcareous soils, from central and east Texas to Illinois and occasionally in Louisiana. Leaves are obovate to elliptic-obovate, 1½ to 2 inches long at midstem, and stems and leaves are rough with microscopic barbs. The inflorescence is similar to that of fragrant goldenrod. It is reported to be good deer forage.

Range: Eastern Texas and eastern Oklahoma to Florida, extending north to southern Ohio, Vermont, and New Hampshire.

Perennial. **Stems** 50 – 150 cm tall, glabrous or pilose in lines; **leaves** simple, alternate, entire or sparsely serrate, glabrous except for ciliolate or scabrous margins, linear-lanceolate, reticulate-veined, 4 – 16 cm long, 5 – 15 mm wide, gradually reduced up the stem; **inflorescence** variable, but usually a conical panicle of numerous racemes; **racemes** bracteolate; **heads** secund along upper side of raceme, 6- to 8-flowered, 4.0 – 4.5 mm long, **bracts** greenish yellow, 2.3 mm long; **flowers** with both tubular and ligulate corollas, rays yellow, conspicuous; **achene** setose.



Vanilla Trilisa—*Trilisa odoratissima* (Walt. ex J. F. Gmel.) Cass—*(Carphephorus odoratissimus* (Walt. ex J. F. Gmel.) Hebert)

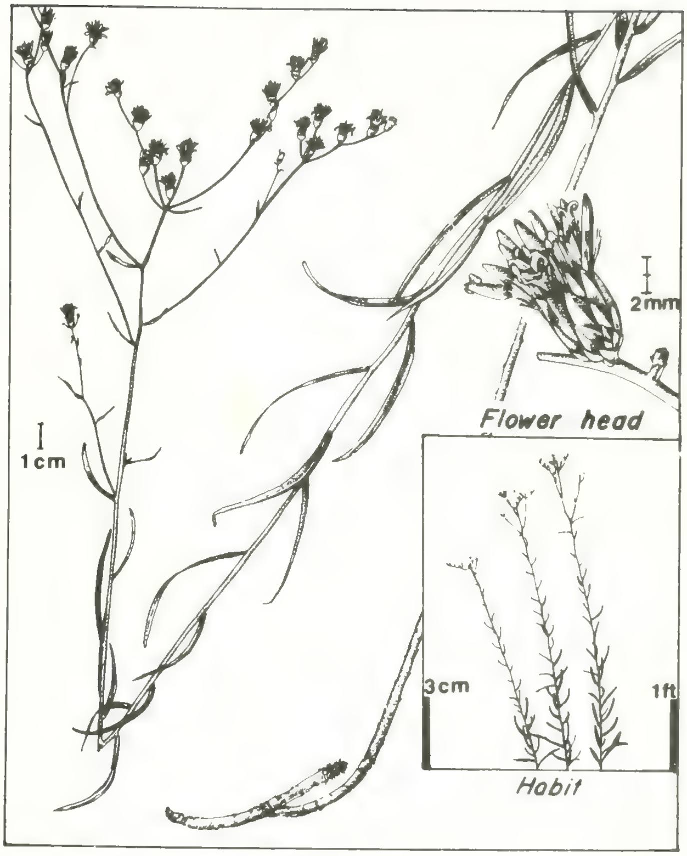


This plant, perhaps better known as deers-tongue, is an erect, stout perennial growing 2 to 5 feet tall on low open pine forests east of the Mississippi River. Its stems and leaves are hairless and its purple flowers are in a flat-topped terminal cluster. Although the leaves have the scent of vanilla, the plant is not the source of true vanilla. The leaves contain coumarin which is used as a flavoring agent in tobacco and various medicinal compounds. Vanilla trilisa is nutritrious and palatable to livestock during spring and early summer. In south Georgia grazing trials, it was relatively high in protein and phosphorus content during the spring and higher in calcium than any of the grasses. Hairy trilisa, *Trilisa paniculata* (Walt. ex J. F. Gmel.) Cass., occurs throughout the range of vanilla trilisa, but has a more compact purple-flowered inflorescence and is hairy throughout. The trilisas are most abundant on the sandy pine flatwoods sites of Florida and Georgia, but are not abundant enough to contribute more than a minor part of the cattle diet.

Range: Southeastern Louisiana to Florida and North Carolina.

Perennial. **Stems** 80 – 200 cm tall, glabrous; **basal leaves** elliptic to oblanceolate, 1.0 – 3.5 dm long, 2 – 7 cm wide, obtuse, crenate to entire, base attenuate; **stem leaves** alternate, usually fewer than 30, ovate to elliptic, half clasping; **heads** in corymbs, the lateral branches usually overtopping the terminal; **corollas** rose purple, 4 – 5 mm long; **pappus** tawny to purplish, 3 – 4 mm long; **achene** about 2 mm long, 10-ribbed, dark brown or black.

Texas Ironweed—*Vernonia texana* (Gray) Small



Several ironweeds occur across the southern states. The most common are robust showy weeds with purple flowers growing in roadside ditches and other disturbed moist habitats. Texas ironweed is not usually robust and is apparently the only narrow-leaved ironweed on well-drained southern pine sites west of the Mississippi River. Early leaves resemble those of swamp sunflower, with which it is often confused. Stems of ironweed are glabrous; those of swamp sunflower are hairy. Also, ironweed flowers by midsummer; swamp sunflower does not bloom until fall. While the larger, weedy ironweeds are undersirable as livestock forage, Texas ironweed may be grazed occasionally by cattle and deer in the spring. However, the plant seldom occurs in abundance.

Pinebarrens ironweed, *Vernonia angustifolia* Michx., occurs on sandy well-drained pine sites from southeast Mississippi to North Carolina. Three varieties of pinebarrens ironweed are recognized, based mainly on the shape of the floral bract tips. Both Texas and pinebarrens ironweeds hybridize with several other species of *Vernonia.*

Range: Texas and Oklahoma to southwest Mississippi and southwest Arkansas.

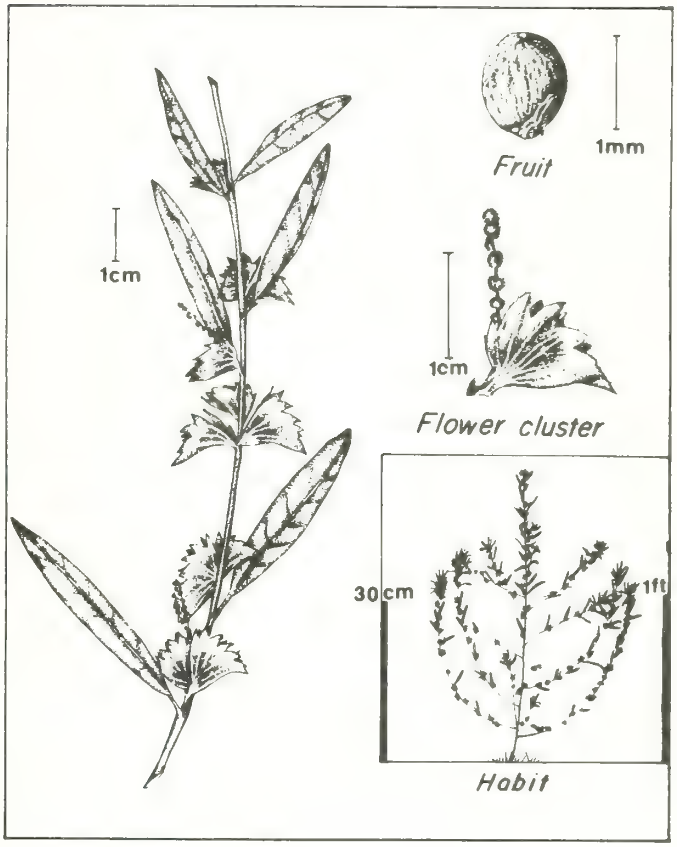
Perennial. **Stems** erect, 40 – 100 cm tall, glabrate to puberulent; **leaves** cauline, scattered, linear to linear-lanceolate, 6 – 13 cm long, 0.2 – 1.4 cm broad, acute, remotely serrate (sometimes prominently toothed), attenuate to a short petiole, scabrous above, scabrous to puberulent beneath, margins revolute; **inflorescence** loose and open; **heads** 15- to 25-flowered, involucre broadly campanulate, 4 – 6 mm high, 5 – 7 mm wide; **phyllaries** imbricate, greenish purple, ciliate, tips acute to short-acuminate; **pappus** brownish to straw colored, often tinged with purple; **corollas** 9 – 11 mm long; **achenes** 1.5 – 3.0 mm long.

Miscellaneous Forbs

Although the most abundant and important forbs on southern forest range are in the composite and legume families, many other families are represented. These miscellaneous forbs vary in size, form, appearance, and habitat. They range from insectivorous sundews, *Drosera* spp., scarcely larger than a dime, to the robust pokeweed, with specimens occasionally attaining 10 feet. Some—such as butterfly milkweed—have brilliantly colored flowers, while many are drab and inconspicuous. Numerous species inhabit only open land; others tolerate heavy shade.

Few are important as forage for cattle; the majority rarely grow in quantity. Many contribute to a diversity of food plants for deer and other wildlife, especially birds. All are fire tolerant and most o those that compete successfully on undisturbed native range are perennials. Descriptions of several o the most common follow. Southern bracken, though not a flowering plant, is included in this group.

Slender Copperleaf—*Acalypha gracilens* Gray



The copperleafs, also known as three-seeded mercuries, are annuals of the spurge family (Euphorbiaceae). Slender copperleaf occurs throughout most of the eastern United States. Like most annuals, it attains greater abundance and larger plant size on sites with little or no competition from perennial plants. Plants on undisturbed sites may have simple stems no more than 6 inches tall, while on firelines, roadsides, and other relatively bare sites, plant height may reach 2 feet, and stems may have many lateral branches.

A distinguishing characteristic of slender copperleaf, and copperleafs generally, is the peculiar leaf-like pistillate flower bracts in the axil of almost every leaf on the plant. Separate male and female flowers are produced, with the female flowers at the base of a spike of male flowers. The coarsely toothed bract conceals the female flowers and the three-seeded fruit it produces. Male flower spikes protrude from the bract and may be as long as half the length of the subtended leaf. Largest leaves are about 1½ inches long and less than ¼ inch wide, with petioles less than one-fourth the length of the blades.

Under average range conditions, slender copperleaf produces little herbage and is not considered valuable as livestock forage, although it is a high-use deer food plant. Seeds are eaten by doves, quail, and other birds, but it is not considered an important wildlife food plant except on disturbed areas where slender copperleaf plants are abundant and well developed.

Other southern copperleafs include Virginia copperleaf, *Acalypha virginica* L., a common agricultural weed that looks like slender copperleaf but has petioles one-fourth to one-half the length of the leaf blades, and hophornbean copperleaf, *A. ostryifolia* Riddell, which has staminate flowers in leaf axils and pistillate flowers in terminal spikes. Both may reach 1½ feet in height and have finely toothed leaf margins.

Range: Texas to Florida, extending north to Wisconsin, Indiana, and New Hampshire.

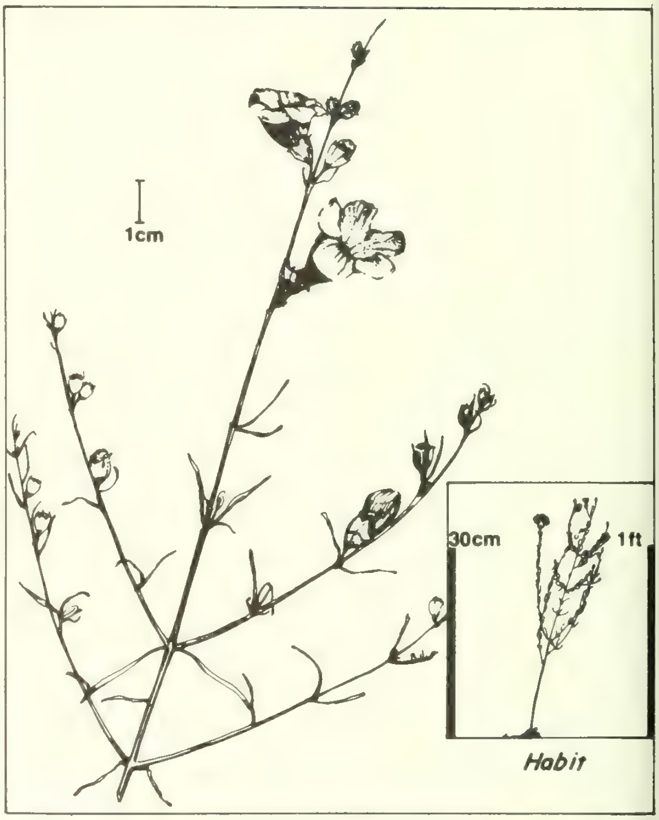
Annual. **Stems** to 80 cm tall, simple or branched, with short ascending-appressed pubescence; **leaves** elliptic to elliptic-lanceolate, 2 – 6 cm long, 0.5 – 2.0 cm wide, petioles of principal leaves 0.4 – 1.5 cm long; **flowers** in axillary spikes with one to five pistillate flowers near the base, and staminate flowers above; **pistillate bracts** with 5 to 13 triangular teeth; **capsule** about 2 mm in diameter, 3-seeded, pubescent; **seeds** reddish to black, ovoid, 1.2 – 1.8 mm long.

Purple Gerardia—*Agalinis purpurea* (L.) Pennell—*(Gerardia purpurea* L.)

The large pink to rose-purple flowers of purple gerardia add color variation to the dominant yellows of the fall-blooming sunflowers on open sandy pinelands. The showy flowers alone make the gerardias noteworthy on southern pine ranges. Several species of *Agalinis* occur throughout the South, but none exceed purple gerardia in general abundance. The gerardias, along with many other plants of the figwort family (Scrophulariaceae), are parasitic on the roots of various plants.

With the exception of perennial gerardia, *A. tenuifolia* (Vahl.) Raf., which has slender rhizomes, all gerardias are slender annuals with narrow, opposite leaves. Seed are minute and not important as wildlife food; forage value for deer and livestock is poor.

Range: Texas to Florida, extending north to Nebraska, Minnesota, and southern New England.



Annual. **Stems** puberulent or scabridulous, striate-angled, 40 – 120 cm tall, profusely branched from upper one-half to two-thirds, the branches spreading; **leaves** opposite, linear to narrowly linear-lanceolate, 1 – 4 cm long, 0.5 – 2.0 mm wide, hispidulous above; **flowers** in axils of upper leaves, forming indistinct racemes; **pedicels** 1 – 4 mm long, usually shorter than the calyx tube; **calyx** tube 3 – 4 mm long, truncate or nearly so, the lobes reduced to minute subulate teeth 0.3 – 2.0 mm long; **corolla** 1.8 – 3.8 cm long, puberulent, the throat lined with yellow, spotted with purple, lanose at the base of the two upper corolla lobes; **capsule** subglobose, 4 – 6 mm in diameter.

Butterfly Milkweed—*Asclepias tuberosa* L.

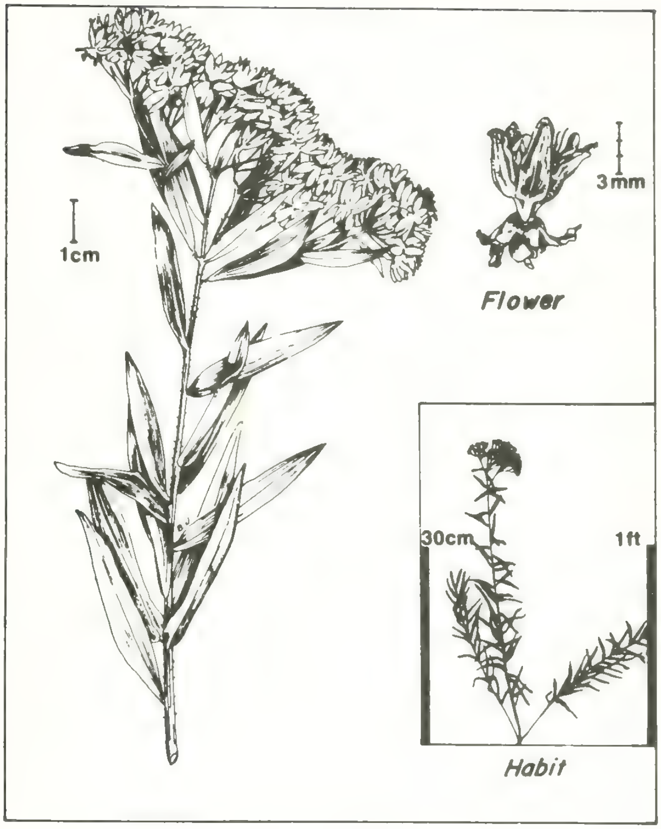
The bright orange flowers of this milkweed seem out of place on the dry sandy sites it inhabits. The color is not common among native plants, and butterfly milkweed is often transplanted to home flower gardens. Flower color varies from red to yellow, leaves are alternately arranged, and the plant does not contain the milky sap generally common to milkweeds. Leaves are numerous, from 1½ to 4 inches long and ⅛ to 1 inch wide, and stems and leaves are coated with white hair.

Red milkweed, *Asclepias lanceolata* Walt., may have flowers of similar color, but it grows on wet sites. About a dozen milkweeds have southwide distribution, but none are generally abundant. Other common milkweeds include: sandhill milkweed, *A. humistrata* Walt., on sandhills and in dry woods; spider milkweed, *A. viridis* Walt., and green milkweed, *A. obovata* Ell., with greenish flowers on dry sites; white milkweed, *A. variegata* L., with white flowers; and broadleaf milkweed, *A. latifolia* (Torr.) Raf., which occurs in open upland woods.

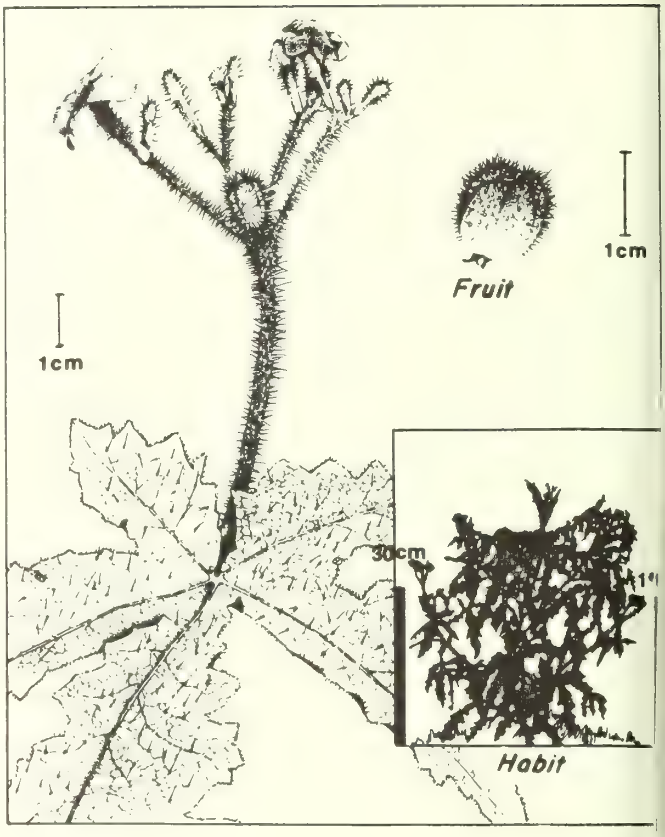
Like other milkweeds, butterfly milkweed is poisonous to livestock, although it is seldom abundant enough to be considered a hazard. The plant has been used in Appalachia to treat rheumatism and as an emetic. Colloquial names include "swallow-wort," "pleurisy-root," and "chigger-weed."

Range: Arizona to Texas and Florida, extending north to Colorado, Nebraska, and Minnesota.

Perennial. **Stems** 20 – 80 cm tall, stout, usually solitary from a thick root crown, branching from the upper nodes, hirsute to hispid, sap not milky; **leaves** numerous, alternate, linear to elliptic, obovate, oblanceolate, or hastate, 4 – 10 cm long, 3 – 25 mm wide, pilose or hispid, especially beneath; **inflorescence** consisting of terminal and axillary hemispherical umbels 2 – 5 cm broad; **corolla** red to yellow, the lobes reflexed, 6.5 – 8.0 mm long; **corona** 4 – 6 mm in diameter, lateral hood margins not toothed, horns shorter than hoods; **follicles** erect, 8 – 15 cm long, 1.0 – 1.5 cm broad.



Bullnettle—*Cnidoscolus stimulosus* (Michx.) Engelm. & Gray



One encounter with this viciously stinging plant should provide an indelible mental picture of bullnettle for future recognition. It is found on most deep sandy soils throughout the South, often growing with other members of the spurge family (Euphorbiaceae) such as queensdelight and flowering spurge. Plant height is often less than 1 foot in undisturbed pine understories but may reach 3 feet or more on firelines or other disturbed sites.

Leaves are palmately three- to five-lobed on petioles about as long as the blades. The entire plant is covered with stinging hairs. Flowers are produced in branched clusters at the apex of the main stem and branch tips. Separate male and female flowers are produced in every cluster with each female flower producing a three-seeded capsule. Seeds are about ⅜ inch long and are eaten by bobwhite quail and other birds.

Bullnettle, known as "treadsoftly" or "risky bullnettle" is found east of the Mississippi River. West of the Mississippi River, plants are referred to as Texas bullnettle, *Cnidoscolus texanus* (Muell. Arg.) Small. Texas bullnettle is a coarser, more virulent plant with larger flowers and seeds than the eastern species. Its range extends from Texas into Oklahoma, southwest Arkansas, and central Louisiana. The ranges of the two species are separated by the Mississippi River and a gap of approximately 150 miles in Louisiana.

Range: Southeast Louisiana to Florida and Virginia.

Perennial. **Stems** much-branched, 40 – 100 cm tall, about as wide as tall, hispid with pale aciculate stinging hairs; **leaves** alternate, blades suborbicular in outline, 6 – 15 cm broad, palmately deeply 3- to 5-lobed, hispid with stinging hairs; **petioles** about equal to their blades, hispid; **stipules** inconspicuous, 3 – 4 mm long, deeply 3- to 4-toothed; **inflorescences** terminal, cymose, pedunculate, determinate, the central flower usually pistillate, the lateral staminate; **staminate flowers** with 9 to 10 stamens; **pistillate flowers** with single lobed stigmas; **calyx** of both type flowers 5-lobed, white, tube 1 cm or less long; **corolla** absent; **capsules** 3-locular, oblong, 15 – 20 mm long, hispid; **seeds** three, oblong, 9 mm or less in length, brown.

Woolly Croton—*Croton capitatus* Michx. var. *capitatus*

Woolly croton, an annual of the spurge family, is commonly found on sandy soils throughout the South. It grows sparingly on grazed range unless the range is severely overgrazed. Plants are often abundant along roads and other disturbed sites.

Stems average 2 to 3 feet tall but occasionally exceed 6 feet. The upper one-half to one-third is branched, the branches ascending at 45° or less. Young plants are thickly coated throughout with short brownish or dirty-gray hairs. Toward maturity, the lower stems shed this coating. Hairs divide at the tip into 8 to 10 radiating branches. This starlike (stellate) construction can be seen with low magnification.

Upper leaves are lance shaped with rounded bases. They are 1 to 3 inches long and blades are ¼ to ¾ inch wide. Petioles are one-fourth to one-half the length of the blades. Lower leaves are frequently longer and more oval than the upper.

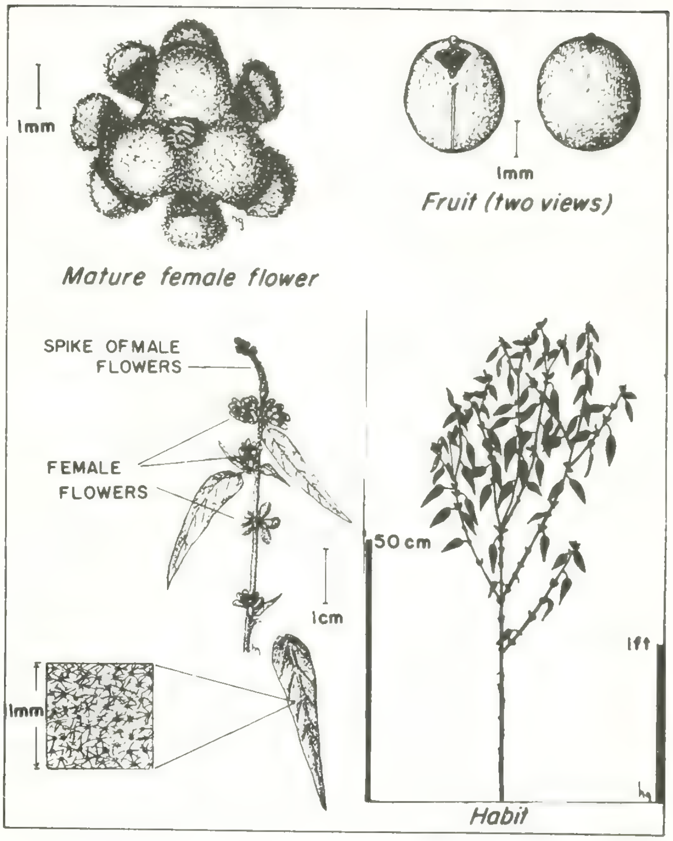
The camouflaging effect of the woolly coating renders flowers and fruits inconspicuous. Flower clusters are terminal or in axils of upper leaves. Each cluster has a spike of male flowers subtended by several female flowers. At least one female flower in each cluster matures into a three-seeded capsule about ¼ inch in diameter. At maturity, the capsule splits suddenly, ejecting seeds with much force. Seeds are about 3/16 inch long, oval, and slightly flattened.

A variety of woolly croton, *Croton capitatus* var. *lindheimeri* (Englem. & Gray) Muell. Arg., is also common southwide. It is distinguishable by its broader leaves with heart-shaped bases and petioles which may be from one-half to as long as the blades. The hair coating is reddish brown—much brighter than that of typical woolly croton.

Woolly croton is toxic to livestock; other species are probably poisonous also. The poisonous substance is croton oil, a violent cathartic. Because cattle usually reject woolly croton, even when better foods are scarce, poisoning is rare. The seeds are a choice food for doves and quail.

Other species with wide distribution are one-seed croton, *C. monanthogynus* Michx., northern croton, *C. glandulosus* var. *septentrionalis* Muell. Arg., and silver croton, *C. argyranthemus* Michx. One-seed croton grows on calcareous soils and develops only one seed per capsule. Northern croton is the only croton with toothed leaves. Silver croton is a perennial with silvery scales on the leaves and other plant parts and is common on loose sandy soils of the lower Gulf Coastal Plain.

Range: Texas to Georgia, extending north to Iowa and New York.



Annual. **Stems** erect to 150 cm tall, branched, thickly coated with short brownish, stellate pubescence; **leaves** 2.5 – 7.5 cm long, 5 – 20 mm wide, petiole 5 – 25 mm long, simple, alternate, entire, lanceolate, tapering to sharp point, base rounded; **flowers** in compact terminal and axillary clusters; **staminate flowers** in a spike above pistillate cluster, pedicellate with five sepals, five petals, 7 – 12 stamens; **pistillate flowers** sessile, apetalous, with six to eight sepals, ovary 3-celled, each cell with a style; **fruit** a globular dehiscent capsule, about 5 mm long and 7 mm wide; **seeds** three per capsule, oval in outline, somewhat flattened.

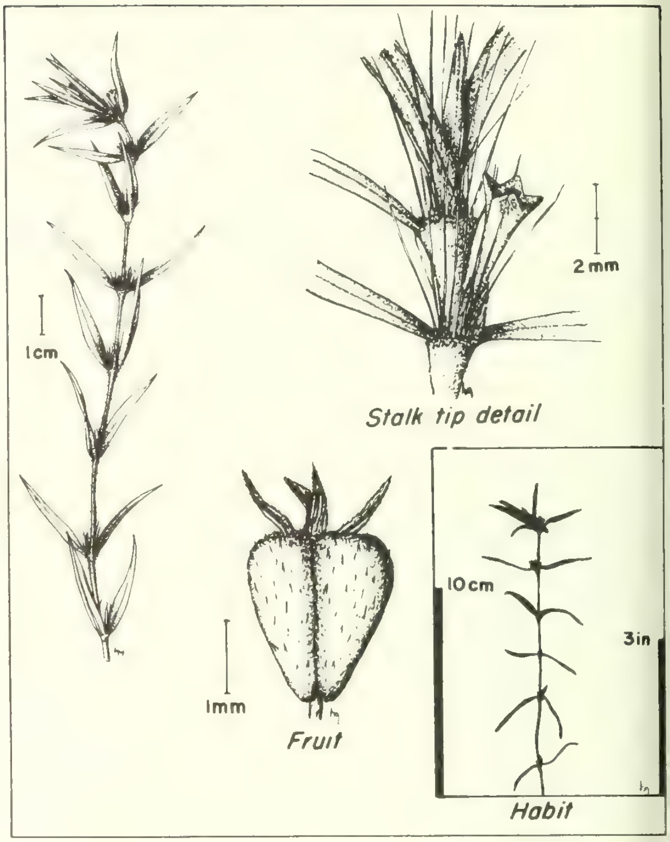
Rough Buttonweed—*Diodia teres* Walt.

Better known as poor-joe, this slender annual is usually present but inconspicuous on sandy pine-bluestem range. In competition with better range plants, poor-joe usually grows as scattered single stems about 4 inches tall. On old fields, firelines, overgrazed range, and other disturbed sites, plants branch profusely, often forming dense, low-growing colonies up to 4 feet in diameter. The opposite leaves are narrowly lanceolate, about 1 inch long and $^{3}/_{16}$ inch wide, sometimes folded and appearing linear. Small, tubular, white or pinkish flowers are borne singly in leaf axils. Bristles arising from the stipules between the opposite leaves provide a distinguishing characteristic. The clusters of bristles persist after fruit and leaves fall.

On freshly burned range, cattle eat young plants along with grass herbage. As plants mature, palatability declines rapidly. Deer eat the foliage, and turkey, quail, and other birds eat the seeds.

Several varieties of rough buttonweed are recognized in the Southeast, based on length of stipular and leaf-tip bristles and nature of stem pubescence. Virginia buttonweed, *Diodia virginiana* L., is a spreading perennial common on poorly drained sites. Cattle eat it readily, and its prostrate habit enables plants to stand heavy grazing. A fleshy taproot allows survival during drought. Although its flowers and fruits resemble those of rough buttonweed, its leaves are elliptical with width about one-third the length.

Range: Texas to Florida, extending north to Kansas, Michigan, and Connecticut.



Annual. **Stems** to 30 cm tall, pubescent, simple or branched, erect to spreading; **leaves** simple, opposite, entire, linear or linear-lanceolate, 1 – 4 cm long, 2 – 3 mm wide, scabrous; **stipules** membranous, with marginal bristles longer than fruit; **flowers** solitary in upper leaf axils, 4-merous; **corolla** white to pink, gamopetalous, 4 – 5 mm long, **calyx** about 2 mm long, sepals acute; **fruit** a 2- or rarely 3-locular capsule 4 – 5 mm long, individual carpels hard and indehiscent.

Button-Snakeroot—*Eryngium yuccifolium* Michx.

Button-snakeroot is a member of the parsley family (Umbelliferae) which includes carrots, celery, and parsnips as well as the deadly water-hemlock, *Cicuta maculata* L., and poison-hemlock, *Conium maculatum* L. It is a deep-rooted perennial, found in open woodlands on a wide range of sites, spreading by short rootstocks. Stems reach 3 feet in height.

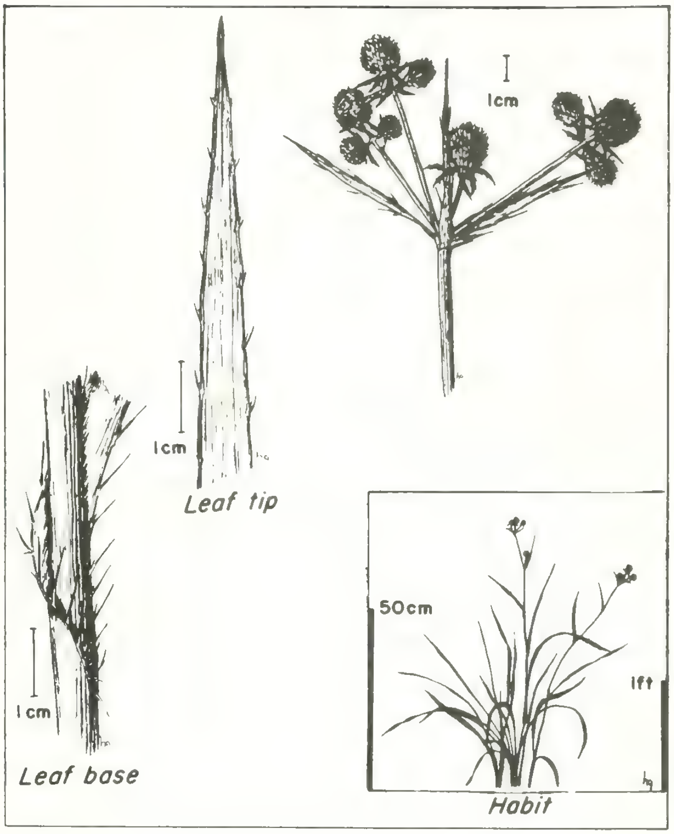
Unlike most members of the parsley family, button-snakeroot has neither divided leaves nor a flat-topped inflorescence. The parallel-veined leaves resemble those of yucca, and the prickly flower heads appear thistlelike. Basal leaves may reach 18 inches in length, but upper leaves are shorter. Blades, ½ to 1½ inches wide at the base, taper gradually to a sharp point. On early leaves, bristles may exceed an inch in length, but on later (upper) leaves, they average less than ½ inch.

The inflorescence consists of round, many-flowered heads, from ½ to more than 1 inch in diameter. Each head terminates a stout branch of the sparsely branched inflorescence. Individual flowers have five inconspicuous white, or sometimes bluish, petals. Because of sharp scales and harsh, persistent styles, the heads appear and feel bristly. Dry inflorescences and leaves persist through the winter.

Cattle graze the leaves before flower stalks emerge, but palatability declines sharply toward maturity. Although this species decreases under heavy use, it rates only fair in forage value.

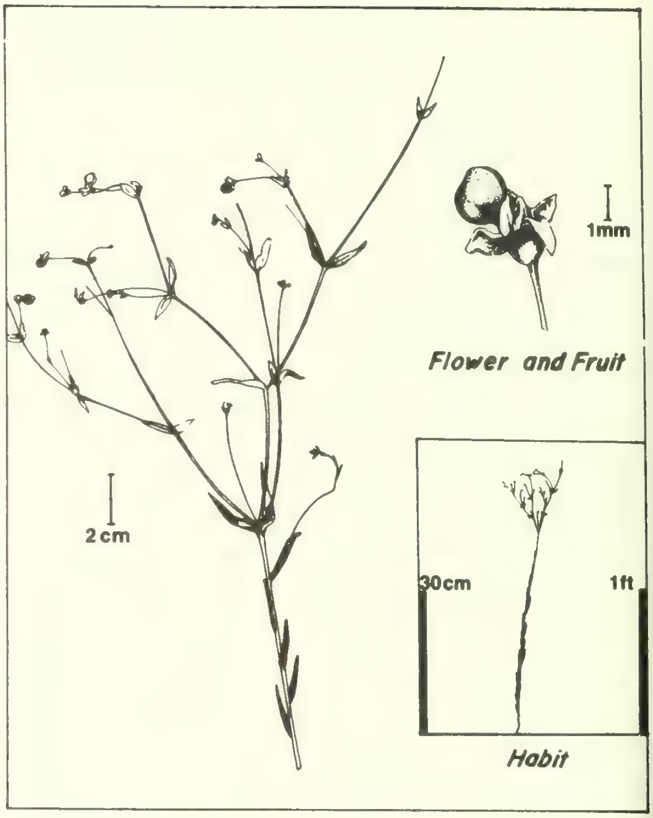
Although several other *Eryngium* species grow in the South, none has the long, bristled, parallel-veined leaves of button-snakeroot. Simpleleaf eryngo, *E. integrifolium* Walt., is a wet-site species with short, narrow, toothed leaves and blue flowers. Another common blue-flowered species, creeping eryngo, *E. prostratum* Nutt. ex DC., is a low plant of moist sites, with toothed, ovate leaves on petioles about as long as the blades.

Range: Texas to Florida, extending north to Kansas, Minnesota, and New Jersey.



Perennial. **Stems** 30 – 100 cm tall, stiffly erect and solitary from woody root crown, glabrous; **leaves** linear, parallel-veined, stiff, with one to three linear spines at regularly spaced intervals along each margin; **basal blades** 15 – 90 cm long, 1 – 3 cm broad, upper blades reduced; **inflorescence** a terminal cyme with one to several flower branches in axils of upper leaves, each branch terminated by a long-peduncled ovate head, usually with two smaller heads below, their peduncles opposite and subtended by leaflike bracts; **heads** many-flowered, each flower above a stiff, sharp bract, terminal head 1 – 3 cm long, 1 – 2 cm wide, subtended by whorl of linear-lanceolate bracts; **flowers** 5-merous, sepals acute, stiff, persistent, shorter than floral bract, petals deciduous, styles two, persistent on fruit, exceeding all other floral parts and bract; **fruit** an oblong cremocarp, 2 – 3 mm long.

Flowering Spurge—*Euphorbia corollata* L.



This slender, somewhat showy plant is one of the most common members of the spurge family in the southeastern United States. Like many spurges, it occurs most commonly on dry sandy soils but may be found on any upland pine site. Flowering spurge is a variable species representing a very variable group within the Euphorbiaceae. Some populations may be hairless, others extremely hairy.

Flowers are produced throughout the growing season. The four or five white "petals" that give the plant its showy appearance are actually the bracts of a cup (cyathium) in which the separate male and female flowers are borne. No true sepals or petals are produced. The male flower consists of a single stamen and there are 10 to 15 in each cyathium; the female flower is a single pistil which produces a three-seeded capsule; seeds are ⅛ to 1/16 inch long.

Most species of *Euphorbia* are poisonous, and flowering spurge has a history of livestock poisoning. Animals do not seek out the green plants, which have milky juice, but will take young plants along with other green forage. Toxicity is not destroyed by drying, and hay containing flowering spurge is palatable to livestock. Seeds are eaten by doves, turkey, quail, and other birds. The plant is rated a high-use plant for white-tailed deer.

Several closely related spurges have petal-like bracts surrounding the flowers but bracts are smaller and may be pink, red, greenish, or white. *Euphorbia zinniiflora* Small has leaves subtending inflorescences about as large as regular stem leaves; flowering spurge has subtending leaves greatly reduced.

Range: Texas to Florida, extending north to Nebraska, Minnesota, and New York.

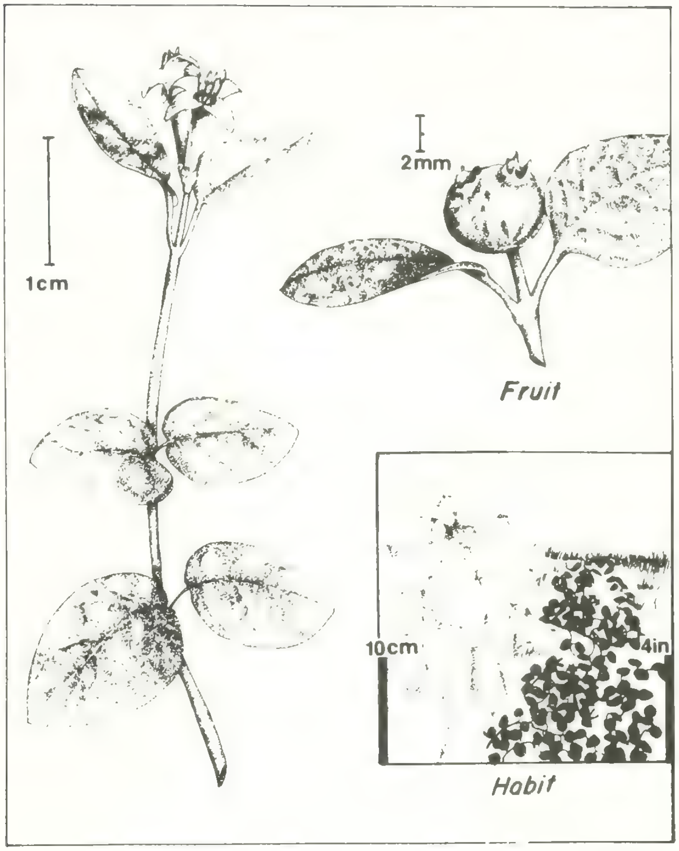
Perennial. **Stems** 10 – 80 cm tall, from stout rootstock; **leaves** alternate below, whorled at base of inflorescence branches, mostly opposite in the inflorescences, entire, linear, oblong, elliptic or oblanceolate, 2 – 7 cm long, 0.3 – 3.5 cm wide, often revolute, sessile or petiolate, glaucous or lighter green beneath; **peduncles** 0.2 – 5.0 mm long; **cyathia** 3 – 10 mm wide; petaloid appendages white, 1 – 5 mm long, longer than wide; **capsule** glabrous, 2 – 3 mm long, pedicels 3 – 4 mm long; **seeds** 2.2 – 2.5 mm long.

Partridgeberry—*Mitchella repens* L.

This attractive, evergreen, trailing herb is found throughout the southeastern states. It is most abundant in low moist woods, such as stream bottoms, and thrives in fairly dense hardwood shade. A pair of white (or sometimes pinkish) tubular, fragrant flowers about ½ inch long produce a red, fused, double berry about ⅜ inch in diameter. Both flowers and berries are aromatic.

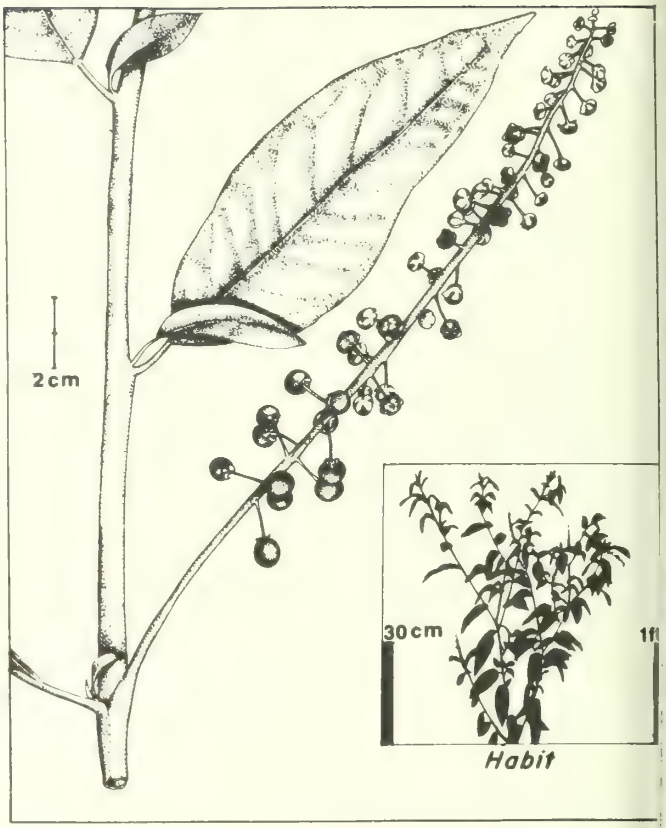
Partridgeberry is in the madder family (Rubiaceae), which includes the ubiquitous annual, rough buttonweed. The attractive foliage of partridgeberry is used for decoration; its small leaves and ease of rooting make it a desirable terrarium plant. Deer eat the foliage, and berries are eaten by bobwhite quail, other birds, and small mammals.

Range: Texas to Florida, extending north to Minnesota and southwest Newfoundland.



Perennial. **Stems** prostrate, puberulent or glabrate; **leaves** opposite, ovate, 8 – 20 mm long, glabrous, leathery; **flowers** in pairs on a short terminal peduncle, the bases of the two calyces usually fused; **calyx** 3 – 4 mm long, lobes minute; **corolla** white or tinged with pink, tube 9 – 14 mm long, lobes ovate, 3 – 4 mm long, pubescent on the inner surface; **stamens** four, well exserted; **berry** red (rarely white), paired, fused, 7 – 10 mm broad, aromatic.

Pokeweed—*Phytolacca americana* L.



Pokeweed is a common "barn-yard" plant throughout the eastern one-third of the United States and adjacent Canada. On forest range it is found primarily along fence rows and on disturbed site such as windrows on recently cleared areas. Height is commonly 6 feet or less, but on cleared, productive sites with little competition plants may grow to a height of 10 feet.

The broad, smooth leaves are from 3 – 12 inches long. Flowers are produced from May until the first frost, and the shiny, dark purple berries hang in 2- to 6-inch long clusters attached opposite the upper leaves on each stem and branch. Stems and flower stalks are purplish.

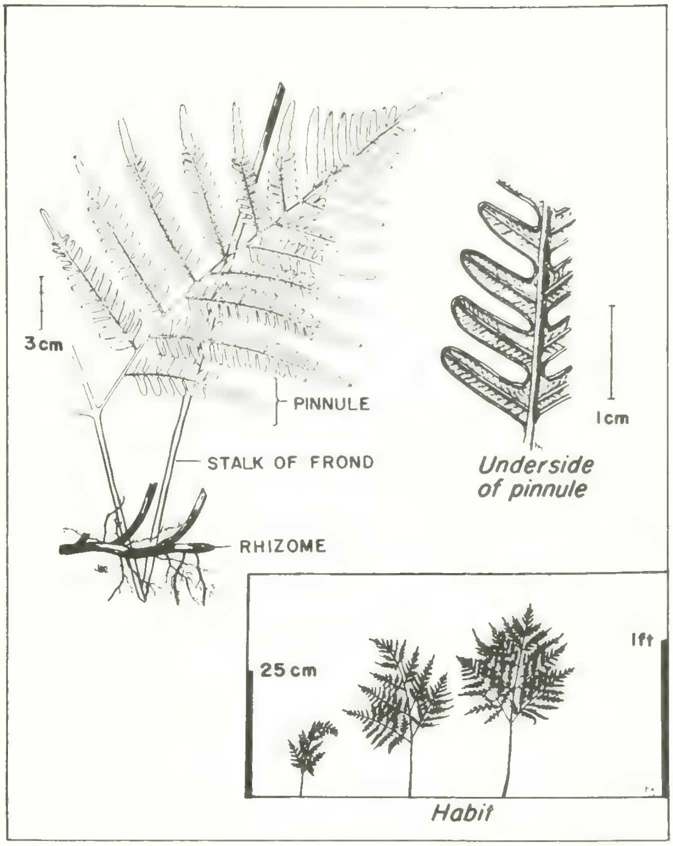
Although pokeweed can be poisonous to humans and livestock, poisoning is rare. Young shoots, when properly prepared, are safe for human consumption. The plant has an unpleasant smell and is unpalatable to grazing animals. The large fleshy taproot is the most poisonous part, and pigs have been poisoned by eating the roots. Deer eat the plant during spring and early summer, and several species of birds and small mammals utilize the berries. Mature berries are slightly flattened, about ⅜ inch in diameter, and each normally contains 10 seeds.

A form of pokeweed with erect rather than drooping flower stalks has been separated as *Phytolacca rigida* Small in some books, but is included in *P. americana* in NLSPN (USDA 1982). The form is apparently common throughout the range of pokeweed, but is not considered a distinct taxon.

Range: Texas to Florida, extending north to southern Ontario and New England.

Perennial. **Stems** 1 – 3 m tall from large fleshy rootstock; **leaves** alternate, glabrous, lanceolate to elliptic-lanceolate, entire, 8 – 30 cm long, 3 – 12 cm wide, acute, base rounded to cuneate, petioles 1 – 5 cm long; **racemes** 5 – 20 cm long, erect to nodding, pedicels bracteate; **flowers** perfect; **sepals** five, green to whitish, 2 – 3 mm long, persistent in fruit; **corolla** absent, stamens 5 to 30, ovary superior; **berry** 5- to 12-carpellate, purplish black, 4 – 6 mm long, 7 – 10 mm in diameter; **seeds** 2.5 – 3.0 mm long, flattened.

Southern Bracken—*Pteridium aquilinum* (L.) Kuhn var. *pseudocaudatum* (Clute) Heller



Southern bracken, a fern of the family Polypodiaceae, is one of the few conspicuous nonflowering plants on pine ranges. It is common on various sites across the South, but is most abundant on well-drained sandy soils under an open pine canopy.

Bracken lacks vertical stems. Coarse, stiffly erect fronds rise to a height of 1 to 5 feet from hairy, underground stems. The frond blade, broadly triangular in shape, consists of opposite, finely divided segments. Fronds usually mature and die before the first frost and the dead fronds stand throughout the winter. Bracken not only spreads by rhizomes, often covering extensive areas, but also reproduces by spores.

Southern bracken is toxic to livestock, with horses more susceptible than cattle. Because fronds are apparently unpalatable except in early spring, and a great quantity must be eaten to produce toxicity symptoms, losses are infrequent. Poisoning has occurred when cattle previously unexposed to bracken were moved in spring to an area with an abundance of bracken. Regular observation of animal condition and forage utilization level should detect bracken utilization in time to prevent losses. Toxicity is apparently due to the breakdown of thiamine in the blood. With yearlong moderate grazing, infested areas normally can be safely grazed, but familiarity with the plant and its toxicity may save cattlemen from severe losses. Utilization of new fronds following a prescribed burn or wildfire in midspring or later should be monitored frequently.

Cattle and deer may graze early growth in spring long with new grass, but as fronds mature, animals ormally reject bracken for more palatable species. It s rated a low-use plant for deer.

Range: Texas to Florida, extending north to Masachusetts, then inland to Oklahoma, Missouri, Indina, and Ohio.

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erennial. **Rhizomes** horizontal, hairy, black, elonate, forking, and extensively creeping; **fronds** tripinately compound, 30 – 150 cm tall, coarse, upright, orne singly and alternately near ends of rhizomes; **tipes** continuous with the rhizome, base dark brown, ith scattered hairs, upper stipe straw colored, glarous; **blades** 20 – 50 cm long, tripinnate, broadly tringular in outline with three main divisions; **pinnules** blong to linear, entire to pinnate, the terminal segents conspicuously elongate, 7 – 15 times longer an broad, margins revolute to entire or undulate; **ri** marginal, mostly continuous; **sporangia** borne tween the modified inrolled margin of the pinnule gment (outer indusium) and the indefinite inner dusium; **spores** minute.

Narrowleaf Mountainmint—*Pycnanthemum tenuifolium* Schrad.

This aromatic member of the mint family (Labiatae) is common throughout the South, growing in roadside ditches, firelines, stump holes, and other moist places, as well as dry prairies and upland forests. Like many other members of the mint family, it has four-angled stems, opposite leaves, and small tubular two-lipped flowers. Leaves are about 1/16 inch wide and ½ inch to 2 inches long. Small heads of white to pinkish, purple-dotted flowers are in terminal clusters at the tip of each branch. The entire plant is hairless.

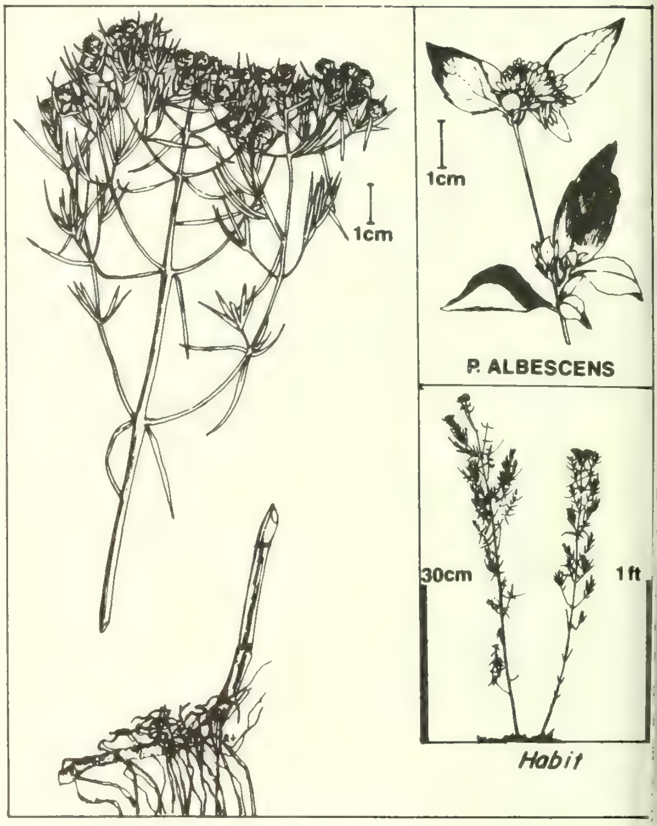
Slender mountainmint, *Pycnanthemum flexuosum* (Walt.) BSP., has been confused with narrowleaf mountainmint; in several books, the two species names are shown to be synonymous. However, *P. flexuosum* has broader leaves—to over ½ inch—and has fine grayish hairs on all surfaces or at least on stem angles and midribs of leaves. Whereas narrowleaf mountainmint is found southwide, *P. flexuosum* does not occur west of Alabama.

Whiteleaf mountainmint, *P. albescens* T. & G., is almost as common as narrowleaf mountainmint from east Texas and Missouri to Florida. Leaves of whiteleaf average about 1½ inches long and ½ inch wide, widest near the middle or slightly below. The terminal one-half to two-thirds of each margin has six to eight widely spaced shallow teeth. Upper leaf surfaces of lower leaves are dull olive green and lower surfaces are greenish gray. Upper leaves and inflorescence bracts are conspicuously whitened with a dense but thin coating of grayish-white hair. Cluster mountainmint, *P. muticum* (Michx.) Pers., similar to whiteleaf, grows in low pinewoods.

Prairie bluet, *Houstonia nigricans* (Lam.) Fern.—which is not in the mint family—has small, narrow leaves, four-angled stems, and flower clusters that resemble those of narrowleaf mountainmint. Early stem leaves of prairie bluet may be 1½ inches long and ¼ inch wide, although later leaves of the upper stem and branches resemble the needle-like leaves of narrowleaf mountainmint. The tubular corolla of prairie bluet flowers is terminated by four small, regular lobes, while narrowleaf mountainmint has a two-lipped corolla typical of the mints.

Mountainmints are not considered valuable as forage for livestock, although they are rated as good deer-food plants and as seed producers for wildlife.

Range: Texas to Georgia, extending north to Minnesota and New England.



Perennial. **Stems** 40 – 120 cm tall, 4-angled, glabrou **leaves** linear to linear-elliptic, 2 – 5 cm long, 1 – 4 m wide, acute, entire, glabrous; **inflorescence** headlike i flat or concave corymbs, each cymule 5 – 10 m broad; **bracts** pubescent, acute; **calyx** pubescent, act nomorphic to slightly zygomorphic, tube 2.5 – 3. mm long, teeth lanceolate, 1.0 – 1.5 mm long, acut **corolla** bilabiate, white to pinkish, often purple-do ted-pubescent, 3 – 5 mm long; **seeds** black, oblon 0.9 – 1.0 mm long, short-pubescent at apex.

Maryland Meadowbeauty—*Rhexia mariana* L.

The meadowbeauties provide color on low, open pinelands during the period of relatively few blooms between the spring and fall flowering peaks. *Rhexia* is the only herbaceous genus of the tropical melastoma family (Melastomataceae) native to the United States. All species have opposite, mainly three-nerved leaves and showy, four-petaled flowers with large yellow stamens. Flower color of the more common species is rose to purple; several species have white-flowered forms, and one species has yellow flowers.

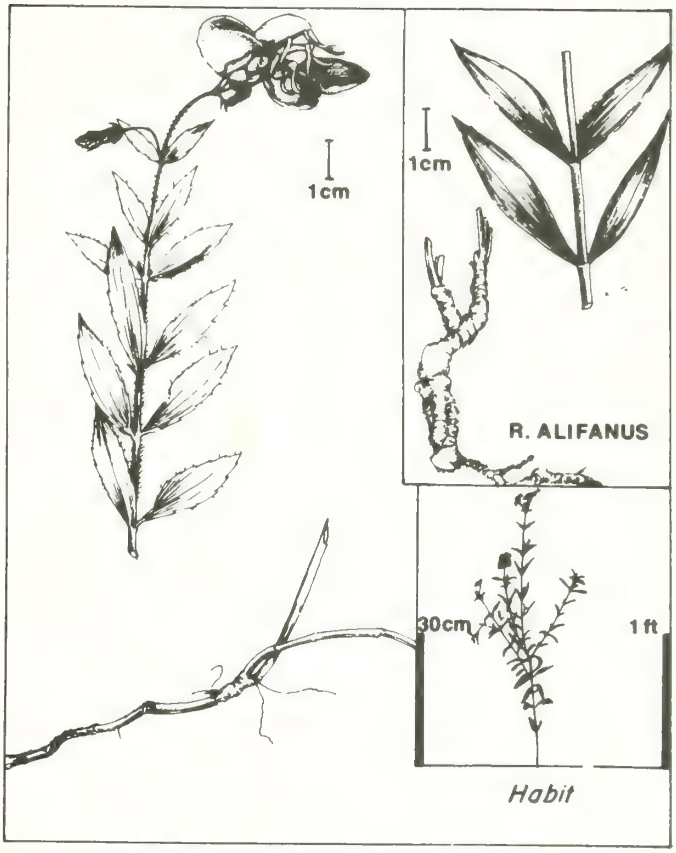
Maryland meadowbeauty, which is one of the most abundant species southwide, grows 1 to 3 feet tall from underground rootstocks. It has lavender, rose-purple, or white petals and hairy stems and leaves. Leaves are up to 2½ inches long. Most leaves are elliptic in outline, but leaf shape is highly variable. Flowers are about 1½ inches wide.

Yellow meadowbeauty, *Rhexia lutea* Walt., has about the same geographic range as Maryland meadowbeauty but is confined to wet pinelands, prairie, or bogs of the lower Coastal Plain. It is slightly smaller than Maryland meadowbeauty, has narrowly elliptic to oblanceolate or obovate leaves and hairy stems and leaves, and is the only *Rhexia* species with yellow flowers. *Rhexia petiolata* Walt. is a slender, often unbranched meadowbeauty with hairless stems and petals about the color of Maryland meadowbeauty. It is frequently associated with yellow meadowbeauty on bogs and wet flatwoods sites.

The largest species, which may reach 40 inches tall on wet Coastal Plain pinelands from North Carolina to Louisiana, is *R. alifanus* Walt. It is a smooth, hairless plant with a thick spongy root and larger darker-colored flowers than Maryland meadowbeauty. Leaf margins of *R. alifanus* are not toothed, but another species about equal in size, common meadowbeauty, *R. virginica* L., has sharply toothed margins on elliptic to ovate leaves.

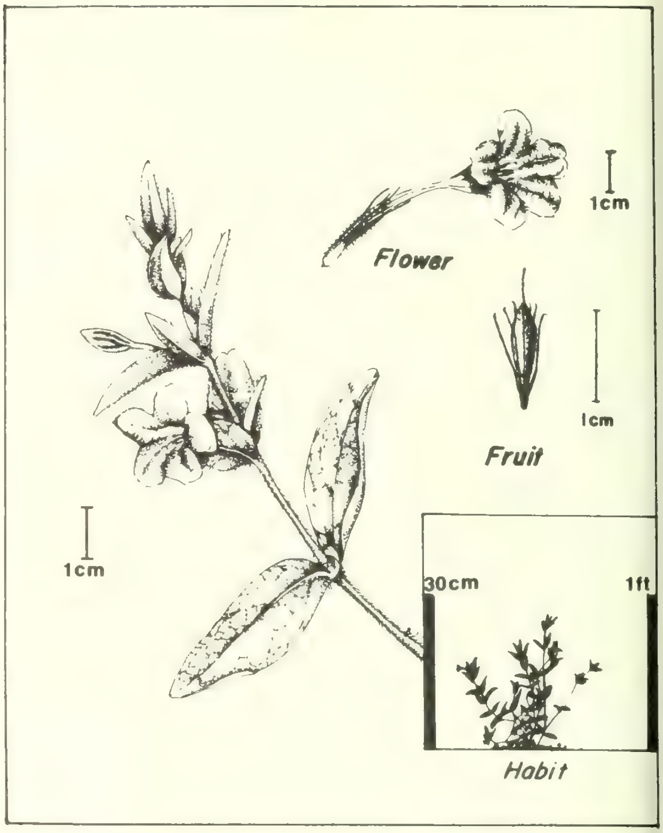
The meadowbeauties are not considered valuable as forage for livestock, although deer eat Maryland meadowbeauty in the spring and summer. The tiny seeds are not important as food for wildlife.

Range: Texas to Florida, extending north to Oklahoma, Kentucky, and Massachusetts.



Perennial. **Stems** frequently colonial from elongate, horizontal roots, to 80 cm tall, hirsute; **leaves** linear, elliptic, lanceolate, ovate, or obovate, to 6.5 cm long and 2 cm wide, sparsely hirsute, 3-nerved, acute, ciliate-serrate, base rounded to attenuate; **sepals** linear, 1.0 – 2.5 mm long; **petals** purplish to white, 10 – 25 mm long; **anthers** 6 – 10 mm long; **capsule** 4.5 – 7.0 mm in diameter, hypanthium 6 – 10 mm long, glandular-hirsute or glabrous, neck about as long as body.

Ruellia—*Ruellia humilis* Nutt.



Several species of *Ruellia* grow throughout the South, and flowers of all are similar: showy violet or purple trumpets with five spreading lobes. Leaves are opposite and in most species broad and attractive, reflecting the characteristics of its tropical family, Acanthaceae, from which come several attractive house plants, including the zebra-plant, *Aphelandra squarrosa* Nees. The native species of *Ruellia* are known by some as "wild-petunias."

Ruellia humilis is found throughout most of the eastern half of the United States. In the South it occurs in dry open woods, prairies, or on rocky hillsides. It differs from another common species, *R. caroliniensis* (Walt. ex J.F. Gmel.) Steud., mainly in the presence or absence of leaf petioles; leaves of *R. humilis* are sessile while those of *R. caroliniensis* have distinct petioles. Moreover, the latter is found in bottomlands and other generally wetter sites than the former.

Stems may be 3 feet tall and branched where herbaceous competition is light, but in fairly heavy herbaceous ground cover, such as found on open longleaf pine sites, stems are 1 foot or less and unbranched. Leaves may be up to 4 inches long and 2 inches wide. Stem and leaves appear bristly with dense white hairs, although hairiness, like other plant characters, is variable. Flowers are up to 2½ inches long, without stalks, with the corolla tube about two-thirds the length, and five broad lobes. The calyx is about 1 inch long, separated almost to the base into five persistent narrow lobes. The slender brownish capsule is only slightly longer than the calyx lobes.

Ruellia ciliosa (Pursh) Long is a dwarf plant on dry sandy soils from Louisiana along the Coastal Plain to South Carolina. Leaves have definite petioles and often form a rosette at ground level. *Ruellia pedunculata* Torr. ex Gray is found on pinelands west of the Mississippi River. Flowers are solitary to several in leaf axils or on axillary branches. Each flower is on a stalk as long as the flower.

Although ruellia seeds have been found in bobwhite quail crops, and deer graze the leaves in the spring, wildlife food value of the genera is limited by its lack of abundance. Its greatest value may be for its showy flowers.

Range: Texas to Florida, extending north to Iowa and Pennsylvania.

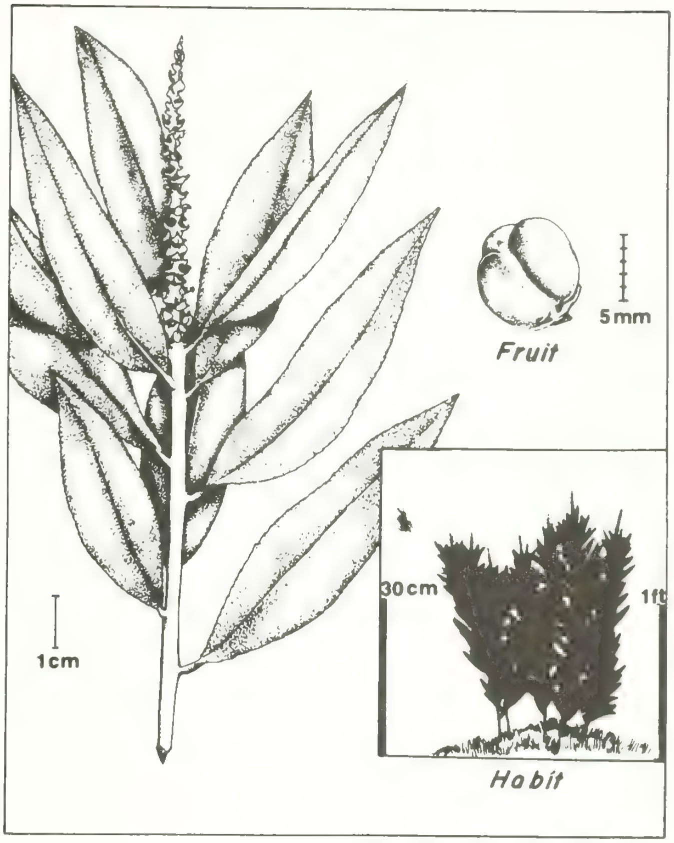
Perennial. **Stems** to 1 m tall, pubescent, branching; **leaves** ovate, elliptic or lanceolate, pubescent, to 6 cm long and 3 cm wide, sessile or subsessile; **flowers** in sessile or subsessile axillary glomerules; **calyx** lobes linear-setaceous, 15 – 25 cm long; **corolla** 2 – 3 cm long, lobes to 1.5 cm long; **capsule** glabrous, 12 – 15 mm long, about 4 mm broad; **seeds** pale, 2 – 3 mm broad.

Queensdelight—*Stillingia sylvatica* L.

This coarse perennial of the spurge family (Euphorbiaceae) grows on dry or well-drained sites throughout the Southeast and as far west as New Mexico. Several stems, up to 32 inches tall, arise from a woody root crown. Each stem is unbranched or may have a whorl of branches below the terminal inflorescence. Pistillate flowers, which produce three-seeded capsules about ⅜ inch in diameter, are borne near the base of a spike of male flowers that may be as long as 5 inches. Leaves are elliptical to lance shaped, about 2 inches long and ½ inch wide, with fine blunt teeth on the margins.

Queensdelight, like other milky-juiced members of this family, normally is not eaten by livestock. *Stillingia treculiana* (Muell. Arg.) I. M. Johnst., a species of west Texas and Mexico, is recognized as poisonous, thus queensdelight should be suspect. Seeds are eaten by bobwhite quail and other birds and small mammals, but because of limited plant distribution and low seed production per plant, queensdelight is not considered a valuable source of wildlife food.

Range: Texas to Florida, extending north to Missouri and Virginia.



Perennial. **Stems** several to many from a woody crown, to 80 cm tall, branching immediately below terminal inflorescences; **leaves** alternate, elliptic to lanceolate or oblanceolate, 3.5 – 9.0 cm long, 1.0 – 4.5 cm wide, margins serrulate or crenulate; **inflorescence** a terminal spike 5 – 12 cm long, pistillate flowers basal, staminate above, conspicuous saucer-shaped glands at base of flower; **capsule** 2- to 3-seeded, 8 – 10 mm long; **seed** 5 – 9 mm long.

Nettleleaf Noseburn—*Tragia urticifolia* Michx.

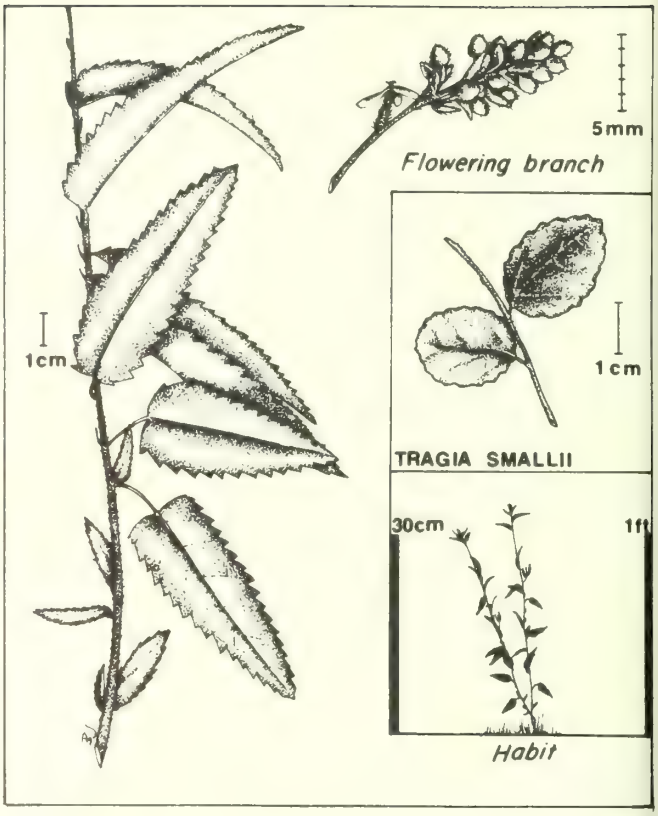
This stinging plant of the spurge family is common in sandy fields and open forests throughout the South. It does not sting as viciously as bullnettle but is much more common. Stems are normally 1 to 2 feet tall, often longer and reclining on more shaded sites. Leaves are alternate and may be less than 1 inch to 3 inches long; width is slightly less than half the length. Width is greatest near the base, and the straight or shallowly heart-shaped base and the straight but abruptly converging margins produce a long-triangular leaf shape. Leaf margins are coarsely toothed.

All above-ground plant parts are coated with soft white hairs intermixed with stiff, white, stinging hairs. Like most members of the spurge family, noseburns have separate male and female flowers on the same plant. In nettleleaf noseburn, one or two female (seed-producing) flowers are borne below numerous male flowers in spikes produced in the axils of upper leaves.

Several other noseburns are common within the range of nettleleaf. Wavyleaf noseburn, *Tragia urens* L., is a slightly smaller plant than nettleleaf, with leaves about the same length but narrow, with smooth, almost imperceptibly wavy margins. Leaves are widest near the middle and taper toward both ends. Plant hairs are sparse with no stinging hairs. Small noseburn, *T. smallii* Shinners, is another nonstinging plant common on sandy soils across the South. It is usually 5 to 10 inches tall and leaves are broadly oval to elliptic, with coarsely toothed margins. Heartleaf noseburn, *T. cordata* Michx., is a stinging, trailing or twining plant with heart-shaped leaves whose petioles are about as long as the blade.

Seeds of the noseburns, like those of most members of the spurge family, are excellent wildlife food. Because of low plant densities and low seed production per plant, however, noseburns are seldom listed as valuable food plants.

Range: Texas and Arkansas to Florida and North Carolina.



Perennial. **Stems** 20 – 70 cm tall, erect to decumbent; **leaves** triangular-lanceolate to narrowly ovate, 2 – 6 cm long, 0.5 – 4.0 cm wide, margins simply or doubly serrate, base truncate to cordate, petioles 5 – 15 mm long; **racemes** 1 – 4 cm long in axils of upper leaves, with one to two pistillate flowers below 11 to 40 staminate flowers, staminate bracts shorter than persistent bases of staminate pedicels; **fruit** about 4 mm long and 8 mm broad; **seed** 3 – 4 mm long.

Rose Verbena—*Verbena canadensis* (L.) Britton

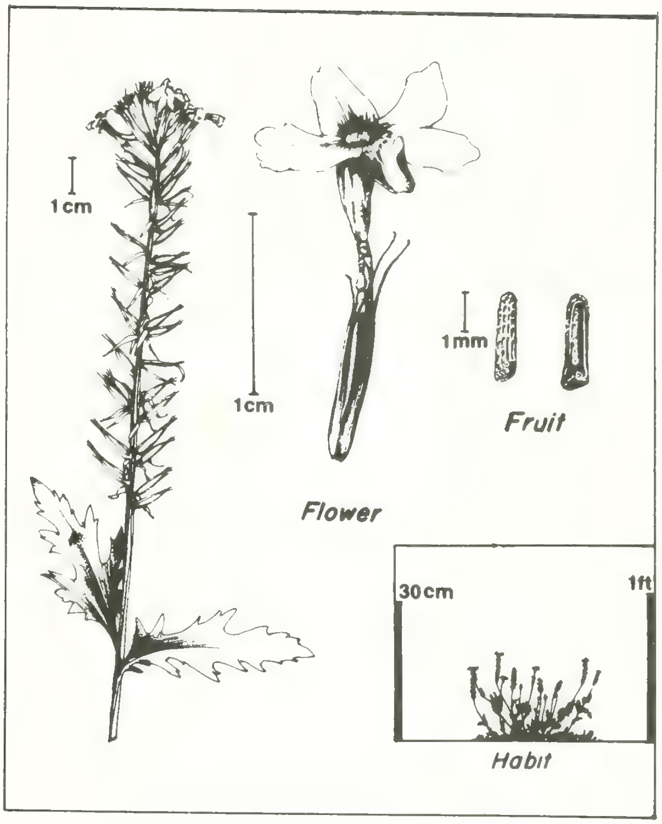
The verbenas or vervains of the Verbenaceae family are represented across the South by approximately 20 species. Several, like rose verbena, are low, prostrate to ascending perennial plants with showy pink to purple (sometimes white) flowers. Others are erect, weedy annual or perennial plants with inconspicuous flowers. The verbenas are close taxonomically to the mint family (Labiatae) and have opposite leaves and four-angled stems, as do many members of the mint family. The two families differ in the following characteristics:

	Verbenaceae	Labiatae
inflorescence	spike or raceme; pedicels less than 1 mm long; calyx less than 5 mm long	not a spike or raceme (if so, pedicels more than 1 mm and calyx more than 5 mm)
flowers	weakly, if at all, zygomorphic	strongly zygomorphic
ovary	lobeless, style apical	4-lobed; style arising between lobes

Leaves of rose verbena are triangular-ovate to lanceolate in outline, although they may be lobed or divided. The hybrid garden verbena, *Verbena hybrida* Hort. ex Vilm., which may escape from cultivation, resembles rose verbena. Its leaves, however, are toothed but not divided, and its flowers may be one of several colors. Moss verbena, *V. tenuisecta* Briq., is a prostrate mat former with finely divided leaves and showy flowers. A tall, unattractive, weedy verbena, *V. brasiliensis* Vell., is common on roadsides throughout the South. There are several attractive verbenas other than the prostrate species; slender verbena, *V. halei* Small, is an example.

Several of the tall weedy verbenas are listed as medium-to-high-use food plants for white-tailed deer in Mississippi. Although other verbenas provide forage for livestock and deer, and seeds are eaten by birds, verbenas are not generally abundant on undisturbed range and are not considered valuable food plants. Rose verbena is included here because of its showy flowers.

The flowers of several species of phlox, *Phlox* spp., resemble those of rose verbena. Although leaves of both phlox and verbena are opposite, phlox leaves have entire margins, while those of verbena are toothed or divided.



Range: Texas to Florida, extending north to Colorado, Kansas, Iowa, and Illinois.

Perennial. **Stems** decumbent or ascending, pilose, 10 – 40 cm long; **leaves** triangular-ovate to lanceolate, pinnately dissected or lobed, petioles 0.5 – 2.5 cm long; **inflorescence** a single spike terminating each branch, erect or ascending, 2 – 15 cm long, densely many flowered; **calyx** 10 – 13 mm long, lobes subulate-setaceous; **bracts** shorter than or equalling calyx; **corolla** tube twice the length of calyx, pink to purple; **seed** cylindrical, about 3 mm long and 0.5 mm broad, surface reticulate-ridged.

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GLOSSARY

achene. A small, dry, one-seeded fruit with a tight, thin, indehiscent ovary wall. Seed attached to ovary wall at one point only.

acicular, aciculate. Needlelike.

actinomorphic. Capable of being divided into equal and similar halves along two or more planes; radially symmetrical (see **zygomorphic**).

acuminate. Tapering gradually to a point.

alternate. Leaves or other parts placed singly at different levels on a stem or axis.

annual. A plant that completes its life cycle in 1 year or less.

anther. The pollen-bearing part of the stamen.

anthesis. The period when anthers disseminate pollen or stigmas are receptive to pollen.

apetalous. Without petals.

apical. At the tip.

apiculate. Ending abruptly in a short, sharp point.

appressed. Closely pressed against.

article. A section of a fruit separated from adjacent sections by a constriction or joint, as in *Desmodium.*

attenuate. Tapering gradually; more gradual than acuminate.

auricle. An ear-shaped projection or appendage.

awn. A bristlelike appendage, often the extension of nerves or veins in floral bracts.

axil. The upper angle between a leaf or branch and the stem to which it is attached.

barbellate. Finely barbed.

beak. A slender, pointed tip sometimes double; appearing as an open or gaping beak.

berry. A fleshy, indehiscent fruit with one to many seeds.

bipinnate. Twice pinnate.

blade. The upper expanded part of a leaf or petal.

bract. A reduced or modified leaf subtending a flower or flower cluster. **bractlet**. Small bract.

bracteate. Having bracts.

bracteole. A secondary bract or bractlet.

bunchgrass. A grass that habitually grows in a well-defined tuft, as opposed to those spreading by stolons or rhizomes.

caducous. Falling early.

callus. The hard, sharp-pointed base of certain grass spikelets or florets.

calyx. The sepals, collectively.

campanulate. Bell shaped.

canescent. Coated with gray pubescence.

capillary. Hairlike.

capitate. Forming a dense or compact cluster; in heads.

capsule. A dry, dehiscent, usually many-seeded fruit, with two or more carpels.

carpel. A simple pistil or a division of a compound pistil.

caryopsis. The one-seeded, indehiscent fruit or grain of a grass, with seedcoat fused to ovary wall.

catkin. A dry, scaly, pendulous spike, usually unisexual, commonly staminate.

caudex. The persistent base of a perennial forb.

cauline. Attached directly to the main stem.

cespitose. In tufts or clumps.

chaff. Small, thin scales or bracts, becoming dry and membranous.

ciliate. Fringed with marginal hairs.

ciliolate. Minutely ciliate.

clavate. Clublike; gradually thickened toward the apex. **clavellate**: the diminutive.

cleistogamous. A type of self-pollinating, non-opening flower.

collar. The outer area of a grass leaf where blade and sheath join.

compound. Composed of two or more similar parts.

cordate. Heart shaped; used primarily to describe leaf bases with heartlike lobes.

coriaceous. Leathery in texture.

corm. A bulblike, but solid, base of a stem, often subterranean.

corolla. The petals, collectively.

corona. A crown-like structure in flowers of *Asclepias*, resulting from modification of the anthers.

corymb. A flat-topped, indeterminate inflorescence, with outer flowers maturing first.

cremocarp. The dry, dehiscent, two-seeded fruit of plants in the family Umbelliferae.

crenate. With coarse, rounded teeth.

culm. The stem of a grass or sedge.

cuneate. Wedge shaped or narrowly triangular, with the point downward.

cyathium. The specialized involucrate inflorescence of *Euphorbia.*

cyme. A flat-topped determinate inflorescence, with the central flowers opening first. **cymule**: a small or few-flowered cyme.

decumbent. Reclining, but with apices ascending.

decurrent. Pointing downward.

dehiscent. Opening at maturity by slits or valves to discharge the contents.

deltoid. Triangular.

dentate. Toothed, with sharp, spreading, coarse indentations perpendicular to the margin.

diadelphous. Having stamens with filaments united in two, often unequal, clusters.

digitate. Handlike; compound, with members arising from one point.

dioecious. Bearing unisexual flowers, with the staminate and pistillate borne on different plants.

discoid. Having only disk flowers.

disk flower. The tubular, regular flowers usually crowded in the center of the flower head in Compositae, as distinguished from the outer, ligulate, ray flowers.

drupe. A fleshy fruit with the inner ovary wall hardened around the one or more seeds in the center.

ellipsoid. Elliptical in outline; three dimensional.

emarginate. Shallow-notched at the tip.

entire. Without marginal teeth or lobes.

equitant. Leaves alternate in two ranks, each leaf overlapping the leaf above.

exserted. Projecting beyond; not included.

fascicle. A close cluster of flowers, leaves, stems, or roots.

filiform. Threadlike.

fimbriate. Fringed.

flabellate. Fan shaped.

floret. A small flower, usually one of a dense cluster, in grasses and sedges; the unit of a spikelet.

follicle. A dry fruit developed from a single ovary, dehiscing along one suture.

forb. A herb other than a grass, sedge, or rush.

frond. The leaf of ferns and fern allies, usually pinnately lobed or divided.

fusiform. Spindle-shaped, broadest in the middle and tapering towards both ends.

gamopetalous. With the petals at least partially joined together.

gamosepalous. With sepals united.

geniculate. Bent abruptly.

glabrous. Devoid of hairs.

glaucous. Whitened with a waxy bloom.

globose. Spherical.

glomerule. A cyme condensed into a headlike cluster.

glume. A chafflike bract, subtending a grass spikelet.

habit. The general appearance of a plant.

hastate. Arrowhead shaped, with basal lobes pointing outward.

head. A dense cluster of stalkless flowers.

herb. A plant that does not develop a persistent above-ground stem.

hirsute. Covered with long, stiff hairs.

hispid. Stiff, bristly pubescent. **hispidulous**: the diminutive.

hyaline. Transparent or translucent.

hypanthium. Floral cup formed by fusion of stamens, sepals and petals.

imbricate. Overlapping, either spirally or vertically.

indehiscent. Not opening at maturity.

indument. Any hairy covering or pubescence.

indusium. Covering of a sorus (in ferns).

inflorescence. The flowering part of a plant.

innovation. A basal shoot of a perennial grass.

internode. The part of the stem between two successive nodes or joints.

involucre. The whorl of leaflike bracts surrounding a flower or flower cluster at its base.

irregular. Having flowers with petals or sepals unequal in size or shape.

keel. The two lower united petals of a papilionaceous legume flower. Also, the projecting midrib on the underside of a laterally compressed grass leaf, glume, or lemma.

lanceolate. Lance shaped; several times longer than broad, broadest below the middle and tapered toward the apex.

lanose. Woolly.

leaflet. A single division of a compound leaf.

legume. A plant of the family Leguminosae; the fruit or pod of such plants that is one-carpelled, dehiscent, usually several-seeded.

lemma. The lower, outermost of the two bracts of the grass floret.

lenticular. Lens shaped; biconvex.

ligule. In grasses a thin, membranous, hairy, or ridgelike appendage on the inside of the leaf where blade and sheath join; in composites the flattened, straplike corolla of the ray flowers.

liliaceous. Possessing characteristics typical of Liliaceae.

linear. Long and narrow, with parallel sides.

locule. One of the chambers in a compound ovary or in the fruit; also applied to the cavities of an anther.

loment. A legume fruit, flattened and strongly constricted between seeds, usually breaking at maturity into one-seeded segments or articles.

membranous. Parchmentlike.

-merous. A suffix indicating the number of parts present in each floral series; e.g., five-merous—a flower with 5 petals, 5 sepals, and 5 stamens.

midrib. The central vein of a leaf.

monoecious. Bearing only unisexual flowers, with the staminate and pistillate borne separately on the same plant.

mucronate. With a short, small, abrupt tip.

nectary. A small, nectar-secreting gland.

nerve. An unbranched, usually straight, vein or rib.

neuter. Without functional stamens or pistils.

node. A joint, especially of grass stems, giving rise to one or more leaves.

oblanceolate. Invert-lanceolate.

oblique. Slanting; attached at an angle.

obovate. Egg shaped with broadest portion at the top.

obovoid. Obovate in outline, three-dimensional.

obsolete. Rudimentary or not evident.

opposite. At the same level, on either side of a stem or axis.

orbicular. Circular.

ovary. The enlarged base of the pistil that encloses the ovules and later ripens into the fruit.

ovate. Egg shaped in outline, broadest below the middle.

ovoid. Ovate in outline, three-dimensional.

palea. The inner or upper bract of the grass floret.

palmate. Arising from a common point, as the fingers of a hand; digitate.

panicle. A compound indeterminate inflorescence of stalked flowers, with the longer, lower branches maturing flowers earlier than the short upper branches.

papilionaceous. Butterflylike; used to describe the irregular corolla in some members of Leguminosae.

papillose, papillate. Beset with tiny, pimple-like protuberances, or papillae.

pappus. A ring of plumose or capillary bristles, scales, spines, or teeth at the tip of the achene in Compositae.

pedicel. The stalk of an individual flower or fruit in a compound inflorescence or of a spikelet in grasses and grasslike plants.

peduncle. A flower stalk supporting either a cluster of flowers or a single-flowered inflorescence.

perennial. Producing above-ground parts from the same root system for at least three growing seasons.

perfect. Having functional stamens and pistil(s) in the same flower.

perianth. Collectively, the calyx and corolla.

perigynium. A flask-shaped sac enveloping the achene in *Carex*.

petal. One of the inner whorl of flower blades; a unit of the corolla.

petaloid. Resembling a petal.

petiole. The stalk by which a leaf, either simple or compound, is attached to the stem.

phyllary. A bract subtending the flower head in Compositae.

pilose. Covered with soft, straight, fine hair.

pinna. A main or primary division of a pinnately compound leaf.

pinnate. A featherlike arrangement; branches, leaflets, lobes, or veins arranged in one plane on two sides of a central axil. **even-pinnate**: with no single terminal leaflet. **odd-pinnate**: with a terminal leaflet.

pinnatifid. Pinnately lobed with clefts more than halfway to midrib.

pinnule. The secondary division of a bipinnate or tripinnate leaf or frond.

pistil. The seed-bearing organ of a flower, composed of stigma, style (when present), and ovary.

pistillate. Having functional pistil(s), but no functional stamens; female.

plumose. Having fine, elongate hairs in a single plane, on either side of a central axis; featherlike.

pod. A dehiscent dry fruit; see legume.

polygamodioecious. Polygamous, but predominantly dioecious.

polygamous. Bearing unisexual and perfect flowers on the same plant.

puberulent. Minutely pubescent.

pubescence. Short, soft hairs. **pubescent**: with pubescence.

punctate. Dotted with depressions, glands, or small colored spots.

raceme. A simple, elongate, indeterminate inflorescence, with stalked flowers.

rachilla. The axis of the spikelet in grasses and sedges.

rachis. The axis of an inflorescence or a pinnately compound leaf; the main axis of a fern frond.

radiate. Arranged around a common center; also said of flower heads in Compositae with ray flowers surrounding a central disk of tubular flowers.

ranked. Arranged in rows.

ray flower. A marginal flower with straplike corolla, in the head of most Compositae.

receptacle. The enlarged or expanded axis which bears either the organs of a flower or the collected flowers of a head.

reflexed. Angled downward.

regular flower. A flower with all members of each whorl similar in shape and size.

reniform. Kidney shaped.

reticulate. Net-veined.

retrorse. Pointed backward or downward.

revolute. With margins rolled under.

rhizome. An underground stem, distinguishable from a root by its nodes, buds, and scalelike leaves.

rootstock. A rhizome or underground stem.

rosette. A cluster of leaves radiating from a very short stem and growing close to the ground.

rotund. Round in outline.

rugose. Wrinkled.

sagittate. Shaped like an arrowhead, the basal lobes pointing downward or backward.

scabrous. Rough to the touch. **scabridulous**: slightly rough.

scale. A general term applied to a variety of small, usually dry, leaflike structures or bracts.

scape. A leafless flower stalk arising from an underground part.

scarious. Thin, dry, membranous; not green.

secund. Arising, or apparently arising, from one side of an axis.

seed. A ripened ovule.

sepal. One of the outer whorl of a flower perianth; a unit of the calyx.

septate. Divided by partitions.

serrate. With sharp, forward-pointing teeth.

serrulate. Finely serrate.

sessile. Not stalked.

setaceous. Bristlelike; bristle shaped.

setose. Having bristles.

sheath. The lower, tubular, stem-clasping part of leaves, especially in grasses, sedges, and rushes.

sinuous. Wavy.

sorus; pl. **sori**. A cluster of sporangia in nonflowering plants.

spathe. The sheathing bract of an inflorescence.

spatulate. Broad and rounded at the apex, with a short, narrowed base.

spike. A simple, elongated, indeterminate inflorescence with sessile flowers.

spikelet. The basic unit of the grass and sedge inflorescence, consisting of one or more florets and a pair of subtending glumes.

sporangium; pl. **sporangia**. The spore case of nonflowering plants.

squarrose. With spreading or recurved bracts or scales.

stamen. The pollen-bearing organ of a flower.

staminate. Having stamens and no functional pistil; male.

standard. The upper petal in pea and pea-like flowers of family Leguminosae.

stellate. Star-like, with radiating branches.

stigma. The pollen-receiving tip of a pistil.

stipe. The stalk of a pistil; the petiole of a fern frond.

stipel. A minute stipule at the base of leaflets of compound leaves in some plants.

stipule. One of a pair of usually foliaceous appendages found at the base of leaf petioles in many plants.

stolon. A horizontal, above-ground branch or runner that roots at nodes.

striate. Having fine longitudinal lines, ridges, or channels.

strigose. With sharp, stiff, straight, appressed hairs which are often basally swollen.

style. The portion of the pistil between the ovary and the stigma.

sub-. Prefix generally meaning "almost" or "about."

subulate. Awl shaped, tapering to apex.

symmetrical. Said of a regular flower having an equal number of petals, sepals, and stamens.

terete. Round in cross section.

throat. The junction of the tube and the expanded part of a united corolla; also the opening in a tubular corolla.

tiller. A shoot growing from the root or base of a stem. Also used as the verb.

tomentose. Densely woolly-pubescent.

tomentulose. Coated with a fine mat of woolly pubescence; finely tomentose.

trichome. Any hairlike outgrowth of the epidermis.

trifid. Split into three.

trifoliolate. Leaves with three leaflets.

trigonous. Three sided; triangular in cross section.

tripinnate. Thrice pinnate.

truncate. With the base or apex transversely straight, appearing cut off.

tuber. A short thickened, usually underground stem or shoot, with numerous buds ("eyes") in the axils of minute, scalelike leaves.

tubercle. A small tuberlike body or nodule.

turbinate. Inversely conical; top shaped.

umbel. A more or less flat-topped indeterminate inflorescence, with pedicels and peduncles arising from a common point.

undulate. Wavy margined or with a wavy surface.

unisexual. Of one sex; either staminate or pistillate.

verrucose. Warty.

verticillate. A whorled, or apparently whorled, arrangement of leaves, inflorescence branches, flowers, etc.

vesture. A term applied to all types of hairiness or coatings on plant surfaces.

villous. Bearing long, soft hairs.

vitreous. Transparent; glasslike.

viscid. Sticky.

whorl. A ring of similar parts around a point, as leaves around a node.

wing. One of a pair of lateral petals on a papilionaceous flower.

zygomorphic. Capable of being bisected by only one plane into equal and similar halves; bilaterally symmetrical (see **actinomorphic**).

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Illustrations and descriptions are given for approximately 125 species of grasses, grasslikes (sedges and rushes), and forbs representative of the pine and pine-hardwood forests of the southeastern United States.

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